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The circuit board fragment

Background

The single most important item of evidence in the Lockerbie case was a tiny fragment of green circuit board, no bigger than a fingernail, which was found in the fragment of shirt that had supposedly been in the same suitcase as the bomb. Known by its police reference number of PT/35b, the fragment allegedly originated from the bomb's timer. In 1990 the Lockerbie investigators identified the timer as a model MST-13, which had been made by a small Swiss company called Mebo. The company's proprietor, Edwin Bollier said that he had made only 20 such devices, all of which had been supplied to the Libyan government in 1985 and early 1986. Abdelbaset al-Megrahi was a partner in a Libyan company that rented office space from Mebo in Zurich. Hence the fragment became the golden thread that linked both him and Libya to the bombing.

The circuit boards were made to order for Mebo by another Swiss company called Thüring. Mebo had ordered more boards than it needed for the 20 timers and still had the surplus ones when the police visited the company in 1990. Bollier handed them all to the police, who passed them on to the Crown's lead forensic expert, Allen Feraday, for the purpose of comparison with PT/35b. In his final report, completed in December 1991, which became the cornerstone of the Crown's forensic case, Feraday noted that the fragment was 'similar in all respects' to the Thüring boards. This was a phrase used throughout the report when describing items that were clearly of common origin. Feraday repeated the assertion in his evidence at Megrahi's trial, thus enabling the judges to infer that the fragment was from one of the 20 timers supplied to Libya.

A few months after Feraday completed the report, in early 1992, the police took one of the Thüring boards to be analysed by a number of academic scientists and circuit board industry experts. The same people had analysed PT/35b two years earlier, when the police were attempting to determine its origin. The analyses appeared to indicate that fragment and the control sample Thüring board, which had the reference number DP/347a, were indeed 'similar in all respects'. There was, however one minor difference, which was separately noted by Dr Rosemary Wilkinson of Strathclyde University and Dr David Johnson of Centre for Surface and Materials Analysis, at UMIST. Both scientists had been tasked with analysing the metallic content of the two items and both noted that there appeared to be a difference in the thin layer of tin that was used to coat copper circuitry.[1] PT/35b's coating - which is generally referred to as plating or tinning – appeared to be almost pure tin, whereas DP/347a's appeared to be a tin/lead alloy. Both scientists speculated that the difference might have been due to the fact that PT/35b had been exposed to the heat of an explosion. Wilkinson recommended that the police test the hypothesis by experiment, but there is no evidence that they commissioned such experiments.

[1] This layer is applied in order to make it easier to attach components.

The scientists' reports were disclosed to the defence, however, it's clear that the scientists - neither of whom were electronics experts - and the defence, were unaware that the difference noted was potentially highly significant. This is because a different production process is required to produce the different types of plating. They were also unaware that Thüring only ever used a tin/lead plating process – a fact we discovered when we interviewed the company's former production manager, Urs Bonfadelli, during preparations for Megrahi's second appeal. We also commissioned independent scientists to test the proposition that exposure to extreme heat could transform tin/lead alloy plating into pure tin. The experiments proved beyond doubt that it was not possible. Taken together, this evidence proved that, contrary to the Crown's key claim, PT/35b could not have originated from one of the 20 timers supplied by Mebo to Libya.

The documents

Documents 1, 2 and 3 all show that both Feraday and the police were aware of the very significant difference between PT/35b and the Thüring circuit boards many years before Megrahi and his fellow Libyan Lamin Fhimah stood trial. All three documents remained hidden from the defence lawyers until shortly before Megrahi returned to Libya in 2009.

Documents 1 and 2 contain the results of previously secret metallurgy tests that had been conducted on PT/35b and the Thüring control sample DP/347a at Feraday's place of work, the Royal Armaments Research and Development Establishment. Each document contains a hand written note by Feraday, dated 1 August 1991. **Document 1** shows the results for PT/35b. The corresponding note states: 'Plating on tracks is of pure tin'. **Document 2** shows the results for DP/347a and contains the note: 'Tinning on the thin tracks is of [approx] 70/30 Sn/Pb.' Sn and Pb are respectively the chemical symbols for tin and lead. The note continues: 'However this may be dipped or roller tinned on top of either the Cu [copper] tracks? Or the Cu tracks with a layer of pure tin?' In other words, he hypothesised that DP/347's tracks may have been plated with pure tin, which was, in turn, plated with tin/lead. As well as being scientifically unfounded, this presupposed a method of double plating that was not used in standard circuit board manufacture (and was certainly not used by Thüring).

Unlike Dr Wilkinson and Dr Johnson, Feraday was an electronics expert who should have recognised the significance of the difference that he had noted. The fact that he was aware of the dissimilarity, begs the key question: why, did he state, both in his report and his court evidence that PT/35b and DP/347a were 'similar in all respects'?

It's not known whether Feraday notified the police and Crown Office prior to November 1991, when Megrahi and Fhimah were charged. If he did, then the Crown Office should have known that the forensic basis of the indictments was fatally flawed. Significantly, documents 1 and 2 each bear a Dumfries & Galloway Constabulary dated 8 November 1999. At that time, the police were interviewing witnesses and collecting evidence on behalf of the prosecution team. The

documents should therefore have been passed on to the prosecutors, who having recognised their importance, should have disclosed them to the defence.

Document 3 is a memo dated 16 March 1990, written by Detective Inspector William Williamson for the Senior Investigating Officer Detective Chief Superintendent Stuart Henderson. It summarises what the police investigation had, by then, discovered about PT/35b and describes the various expert analyses that had been conducted, including the metallurgy tests. The crucial passage reads:

> *Without exception it is the view of all experts involved in the PCB [printed circuit board] industry who have assisted with this enquiry that the tin application on the tracks of the circuit was by far the most interesting feature. The fact that pure tin rather than a tin-lead mixture has been used is very unusual.*

Three months after Williamson wrote the memo, the police learned that PT/35b appeared to match the circuit boards in the MST-13 timers and three months after that, in September 1990, they learnt that MST-13s were made by Mebo. The company's co-owner, Edwin Bollier, told the police that the circuit boards used in the timers had been made to order by Thüring and provided the paperwork to prove it. As the police were aware that PT/35b's pure tin coating was unusual, they should have asked Thüring's production manager, Urs Bonfadelli, what type of plating was used on the Mebo boards. Had they done so, they would have learned that the company only ever used tin/lead alloy, a fact that destroyed the case against Megrahi and Fhimah.

By early March 1992 both Dr Wilkinson and Dr Johnson had reported that the control sample Thüring board DP/347a was plated with tin-lead alloy. Given what the police knew about PT/35b, this should have been enough to alert them to the fact that the fragment did not originate from a Libyan timer, even if they were unaware of the test results recorded by Feraday six months earlier in documents 1 and 2. There is no suggestion that Williamson and Henderson acted improperly, but, had the memo been disclosed before Megrahi and Fhimah stood trial, the defence lawyers would have been alerted to the 'very unusual' comment and would have been able to pursue the issue with Bonfadelli.

In February 2013 I asked the Crown Office under the Freedom of Information (Scotland) Act why documents 1, 3 and 3 had not been disclosed, and who was responsible for the decisions. Under the act, they should have responded within 20 working days, unless there were public interest considerations, in which case they should have informed me within that 20-day limit. It the event I had to wait until 18 June for a response, which was a flat refusal to answer either of my questions.

The clothing evidence doubts

Background

The Crown case relied on the forensic finding that certain blast damaged clothing fragments had been in the same suitcase as the bomb. These clothes were supposedly bought by Megrahi from a shop in Malta belonging to the key Crown witness Tony Gauci. The clothes were linked to the suitcase by Feraday's colleague Dr Thomas Hayes, who devised a categorisation system, which, he claimed allowed him to distinguish between garments that were likely to have been in the suitcase, and those from the surrounding cases. The former, he said contained fragments of the bomb and no fragments of suitcase shell, while the latter contained either no fragments at all, or fragments including suitcase shell. Hayes set out these criteria in the final Crown forensic report, to which Feraday was a co-signatory, and in evidence at trial.

The document

Document 4 is a Crown precognition statement by Feraday, dated 30 March 2000, less than six weeks before the trial opened. In it he states:

> *Tom Hayes established the criteria and I did not feel comfortable using them… The more precise the criteria, the greater the number of items which will fall on the borderline ... It is so difficult to be precise about such classifications. I would not have adopted such strict criteria for the clothing.*

Despite harbouring these doubts on this crucial matter, Feraday signed the report. The Crown did not release the statement to the defence and failed to explore these concerns with him during his trial evidence.

The suppression of forensic tests

Background

According to the Crown case, the bomb suitcase was positioned in the second layer of luggage in one of Pan Am 103's aluminium luggage containers, and it contained between 350 and 450 grams of plastic explosive. The claim was partially reliant upon a series of seven explosive tests, which were conducted in the US in April and July 1989. The five April tests were devised by Allen Feraday, in conjunction with the US Federal Aviation Authority and FBI, and the two July tests were conducted at the initiative of the FAA's lead forensic examiner, Walter Korsgaard.

In all of the tests a replica Lockerbie bomb was packed, along with clothes, into a suitcase, which was in turn placed within an aluminium luggage container and surrounded with other luggage. Varying amounts of plastic explosive were used in the seven tests, ranging from 360 to 680 grams. In each instance the suitcase containing the bomb was positioned close to the surfaces of the container that would have been adjacent to the aircraft's skin. In tests 1, 2, 3 and 5, the suitcase was in the second layer of luggage and in test 4 in the bottom layer.

Following the tests Detective Chief Inspector Harry Bell produced reports setting out the investigators' preliminary conclusions about the Lockerbie bomb. The April tests report states that the test 5 came closest to mimicking the Lockerbie explosion. That test had used 460 grams of explosive and the centre of the charge was 10.5 inches (26 cm) from the floor of the container. This supported the police's belief that the bomb was not planted at Heathrow, but rather originated in Malta, where it had been placed o a flight to Frankfurt and in turn transferred to a Pan Am feeder flight, PA103A, to Heathrow. However, the July tests report revealed that the FAA's lead investigator, Walter Korsgaard, believed the Lockerbie bomb contained at least 1.5 pounds (680g) of explosives and wished to conduct a further test using an actual Boeing 747 aircraft.

The document

Document 5 is a handwritten internal memo by Feraday, dated 8 August 1989, in which he strongly objects to Korsgaard's proposal, complaining that it was 'unnecessary and ill advised and as such should be discouraged'. He adds:

> *I do urge you in the stongest possible terms that Korsgaard be stopped from carrying out any further tests in connection with the Lockerbie investigation.*

More worryingly, he wrote that the additional tests:

> *could readily be misconstrued by any defence counsel as implying some doubts concerning the results of the earlier trials, and as such could be destructively exploited by counsel … It would be foolish and detrimental to the case to allow any errant defence laywer to gain succour from any future*

> *explosions tests designed purely to enhance an opinion as to the charge weight against all previous test results and the scientific findings to date.*

As a forensic scientist, Feraday's duty was to pursue the truth, not stifle work that might contradict his own conclusions. Still less should he have been concerned to thwart defence counsel in any future trial.

The overstretched scientists

Background

Lockerbie was the biggest terrorist attack in UK history and, prior to 9/11, was the biggest committed against western civilians. A vast amount of debris was recovered from hundreds of square miles of open countryside. Despite this, the task of analysing the debris, fell to just two men: Allen Feraday and Dr Thomas Hayes, both of RARDE. Hayes was not even full-time, having resigned in early 1989 and re-employed on a part-time consultancy contract.

Feraday produced only 116 pages of examination notes, most of which were a rough draft of the final forensic report. Hayes's notes were more detailed, but still ran to just 177 pages. Their final joint report described only around 500 debris items.

The documents

Documents 6 and 7 are extracts of Hayes and Feraday's interviews with the Scottish Criminal Cases Review Commission, which the commission undertook as part of its review of Megrahi's case between 2003 and 2007. They reveal that both scientists were burdened with a very heavy workload. In Hayes's interview he states that, at the time of the Lockerbie bombing, he was working on around twelve animal-rights cases. Feraday's was even more hard pressed. He told the SCCRC that he had 'approximately 56 other bombings to work on' during the Lockerbie investigation.

The bitter mistrust

Background

The Lockerbie investigation was upheld as a model of trans-Atlantic cooperation, with the Scottish police and FBI freely trading information and know-how. This was especially the case with the forensic investigation, in which the FBI's lead examiner, Tom Thurman supposedly played a crucial role. In particular, he was credited with the most important breakthrough in the case, which was the identification of PT/35b as part of a Mebo MST-13 timer.

The documents

In April 1991 Thurman requested that he be present during Feraday's examination of a number of items. **Document 8** is a fax dated 5 April from Feraday to the Deputy Senior Investigating Officer James Gilchrist, in which he makes clear that he does not need Thurman present, adding:

> *I also can see no advantage for Thurman if I only examine [the timer] in his presence, because he has already done that himself. Clearly he is seeking entry to <u>all</u> the other exhibits and examination notes, which I am unwilling to supply him. If he comes… I will have to watch him 100% of the time.'*

The FBI subsequently requested that Thurman be allowed to visit RARDE. **Document 9** is a letter from SIO Stuart Henderson to Feraday's boss, Dr Maurice Marshall, dated 11 November 1991 in which he registers his opposition to the request in unusually strong terms:

> *The excuse used by the Americans is that Thurman requires to visit RARDE in order to get access to two electronic components, which would then enable him to furnish his report in the USA. That excuse is not accurate, because it is not necessary for Mr Thurman to examine any components at RARDE to complete his report. This charade is an attempt by Thurman to gain access to RARDE and all the forensic evidence held by Mr Feraday, in order to return to America with the 'poached' information and include it in a report he would submit on behalf of the FBI. In all probability he would then claim that the information contained in that report was in fact the result of his own efforts.*

Document 10 is a further extract from Feraday's SCCRC interview, in which he describes Thurman demonstrating the match between PT/35b and a sample MST-13. He recalls:

> *Thurman wanted us to leave the timer fragment. There was no way that we would do that. At this point the FBI were looking to take over the Lockerbie investigation. The division between the UK investigation team and the US investigation team was tangible … There was something about Thurman's reaction which made me worry that I was being played for a dummy.*

DUMFRIES AND GALLOWAY CONSTABULARY

Police No. _____ Label No. PT 82

Case Against/Incident ABDELBASET ALI MOHMED AL MEGRAHI AND AL AMIN KHALIFA FHIMAH

Description of Article (including identifying serial numbers, features etc.) HMSO FOLDER WITH WHITE STICKER AND No PA 8932 RECORDED IN BLUE INK.

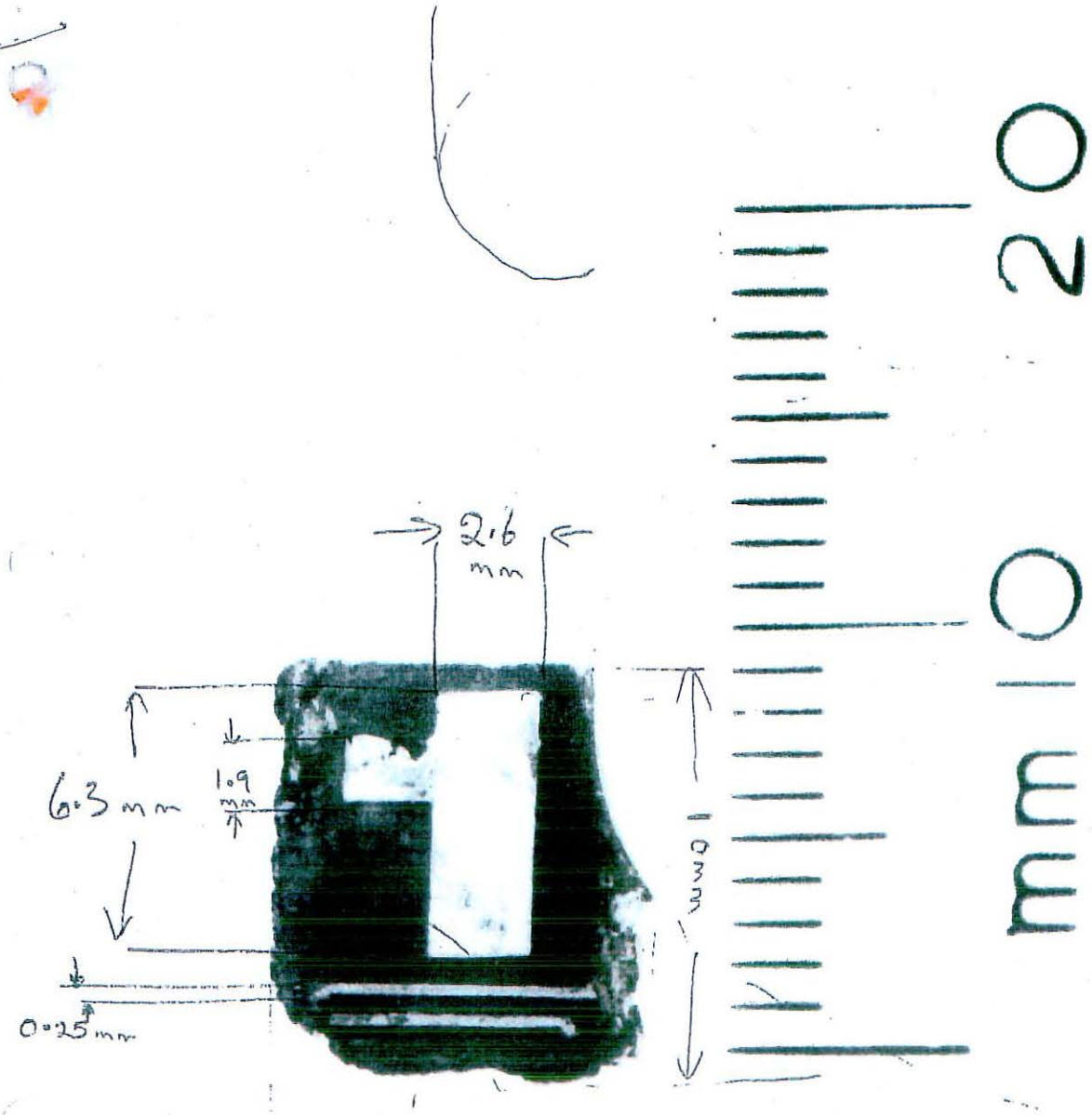
Where Found OERA, FORT HALSTEAD, KENT.

Date 8/11/99

Signature(s) of Person(s) identifying article

1	K Swinson	5		9	
2	[illegible] 01562	6		10	
3		7		11	
4		8		12	

AWF.



Approx 1.6 mm thick
ckt board.

ECTRUM: PP8932 PT/35B TIN PLATE:

IN	=	20	EV/CHAN
PECTRUM LENGTH	=	1024	CHANS
RESET LIVE TIME	=	65535	SECS
ACTUAL LIVE TIME	=	105	SECS
PRESET INTEGRAL	=	65535	CNTS

WINDOW LABEL	WINDOW CENTRE	FIRST CHAN	LAST CHAN	NET INTEGRAL	EFF. FACTOR	%AGE TOTAL
PB1	2340	2100	2580	1503	1.00	1.82
SN	3680	3140	4220	72177	1.00	87.32
CU1	8020	7940	8120	8005	1.00	9.68
PB2	10540	10320	10760	672	1.00	0.81
PB3	12600	12440	12760	228	1.00	0.27
PB4	14760	14660	14860	74	1.00	0.09

Plating on tracks is of pure tin (copper is breaking through from underneath).

AWF

1/8/91

TRUM: FP8932 PT35B THIN LINES

IN	=	20 EV/CHAN
ECTRUM LENGTH	=	1024 CHANS
RESET LIVE TIME	=	65535 SECS
CTUAL LIVE TIME	=	74 SECS
RESET INTEGRAL	=	65535 CNTS

WINDOW LABEL	WINDOW CENTRE	FIRST CHAN	LAST CHAN	NET INTEGRAL	EFF. FACTOR	%AGE TOTAL
		2100	2580	0	1.00	0.00
PB1	2340	3140	4220	46454	1.00	87.32
SN	3680	7940	8120	6744	1.00	12.68
CU1	8020	10320	10760	2	1.00	0.00
PB2	10540	12440	12760	0	1.00	0.00
PB3	12600	14660	14860	0	1.00	0.00
PB4	14760					

Plating on the two thin lines is of pure tin (Cu breaking through from underneath).

AMDF.

1/8/91

Police No. _____ Label No. PT 88

Case Against/Incident ABDELBASET ALI MOHMED AL MEGRAHI AND AL AMIN KHALIFA FHIMAH

Description of Article (including identifying serial numbers, features etc.) BUFF FOLDER CONTAINING FTIR SPECTRA PRINT OUTS

Where Found DERA, FORT HALSTEAD, KENT

Date 8/11/99

Signature(s) of Person(s) identifying article

1 _____ 5 _____ 9 _____

2 _____ 6 _____ 10 _____

3 _____ 7 _____ 11 _____

4 _____ 8 _____ 12 _____

DUMFRIES AND GALLOWAY CONSTABULARY

AWF

DP-347A - Set 7

SPECTRUM: PP8932 DP347A TRACKS

GAIN	=	20 EV/CHAN
SPECTRUM LENGTH	=	1024 CHANS
PRESET LIVE TIME	=	65535 SECS
ACTUAL LIVE TIME	=	97 SECS
PRESET INTEGRAL	=	65535 CNTS

WINDOW LABEL	WINDOW CENTRE	FIRST CHAN	LAST CHAN	NET INTEGRAL	EFF. FACTOR	%AGE TOTAL
PB1	2340	2100	2580	9097	1.00	26.76
SN	3680	3140	4220	23486	1.00	69.07
CU1	8020	7940	8120	32	1.00	0.09
PB2	10540	10320	10760	1021	1.00	3.00
[illegible]	12600	12440	12760	343	1.00	1.01
[illegible]4	14760	14660	14860	25	1.00	0.07

Timing on the thin tracks is of ≈ 70/30 Sn/Pb. However this may be = dipped or other tinned ~~ones~~ on top of either the Cu tracks? or the Cu tracks with a layer of pure tin?

AWF

1/8/91

INTERNAL MEMORANDUM

From:
Det. Insp. Williamson,
L.I.C.C.
16.3.90.

To:
Det. Ch. Supt. Henderson,
Senior Investigating Officer,
L.I.C.C.

PRODUCTION PT35 - Small Fragment of Unidentified Circuit Board

With reference to subject I have to report that during examination of a piece of shirt material Production No. PI995, Scientists at R.A.R.D.E. discovered a small fragment of green coloured circuit board along with other materials embedded into the shirt. The piece of shirt material (PI995) was identified as showing characteristic damage of close explosive involvement. The other materials included small particles of black plastics identical to the case of a Toshiba Bombeat Cassette Recorder Model SF16 and a small piece of paper now identified as part of the Operational Manual of a Toshiba Bombeat Cassette Recorder.

The fragment of circuit board was removed from the shirt and given a part number, PT35. This fragment was also identified as displaying damage caused by close explosive involvement and also appeared to have been subjected to extreme high temperatures.

From their examinations, Scientists concluded that these items had been contained in the suitcase containing the Improvised Explosive Device and in very close proximity to it.

The fragment PT35 is part of a fibreglass laminate circuit board. The circuit board which controls the Toshiba Bombeat Cassette Recorder Model SF16 is constructed on Phenolic paper, therefore though closely involved with debris from the Toshiba Recorder Production PT35 was not part of its original construction.

The discovery of item PT35 is considered by Scientists to be of extreme importance as its condition and location suggest that it may have formed part of the I.E.D. timing mechanism and as such its identification if possible could be critically important to the progress of the investigation.

Description PT35

The physical size of the fragment does not make its identification easy. The longest edge is 1 centimetre and of the tracking pattern or "artwork" of the printed circuit, only two tracks and a "contact pad" in the shape of the figure one remain. The fragment has a curved edge of .6 centimetres in diameter, the manner in which this edge has been cut suggests that it has been milled and is of professional manufacture. On the reverse side of the fragment from the artwork the board is green in colour which shows the application of a solder mask and this is another indication of professional manufacture.

Visit to BKA Headquarters, Meckenheim, Federal Republic Germany

On 16th January 1990, in pursuance of enquiries and in an effort to identify production PT35, Detective Inspector Williamson from L.I.C.C. accompanied by Mr. A. Feraday, R.A.R.D.E. visited Meckenheim, West Germany, and were given the opportunity to view a large number of productions recovered by the BKA during their Operation 'Autumn Leaves' from members of the group PFLP-GC. These productions consisted mainly of electronic devices and components such as clocks, radios, timers, circuit boards, lengths of wire, solder, etc. All items which contained circuit boards were opened and examined internally by Mr. Feraday but none had a circuit board resembling PT35. During this examination a Krups make quartz alarm clock type 3.202.22 was seen to have the circuit board stripped from it. This item had the BKA Production No. 1.2.1.8.1.12.

Following the visit to Germany enquiries were carried out from L.I.C.C. to have this matter resolved with the following results.

Enquiry with the Krups company revealed that all clocks bearing this company name are manufactured for them by the company KIENENGER OBERGFELL, also called KUNDOR. This company were contacted and when questioned regarding the works of the clock advised that they purchase all works for clocks from the company UHERN TECHNIK SCHWARTZWALD (UTS). Contact with UTS revealed that the circuit boards used by them in the manufacture of clock works are supplied to them by a company of the name Moker. On contact with Moker it was learned that the circuit board within the Krups clock, type 3.202.22 is a Phenolic paper board bearing the identifying number 580580 and not a board of fibreglass construction. In response to the enquiry, Moker company dispatched a complete range of all circuit boards manufactured by them to L.I.C.C. This range included the board 580580 and this sample bears no resemblance to PT35.

In view of the aforementioned critical importance to identify the origin of PT35 and in the absence of any obvious assisting features such as manufacturers' logo or numbers, the following lines of enquiry have been and continue to be followed in an attempt to identify it by breaking down its physical structure.

The following is an explanation in basic terms of the structures and manufacturing process used in the production of printed circuit boards and of the avenues of enquiry considered worthy of pursuit.

Printed Circuit Board Manufacture Using Epoxy Glass Laminate (Fibreglass)

There are three basic manufacturing steps as follows:

Step 1 The laminate manufacturer buys in basic raw materials,

1. Epoxy Resin.
2. Glass Cloth.
3. Adhesive (or buttercoat).
4. Copper foil.

The epoxy resin is slightly altered to suit the specific purpose to which the completed PCB will be put, e.g. certain chemicals are added for their fire resistance properties etc. Each laminate manufacturer differs in the type of chemicals and the quantities which they add making their resin slightly different from that of their competitors.

The chosen number of sheets of glass cloth to attain the required strength and thickness of the board are impregnated with the epoxy resin. A sheet of copper foil to the required thickness, treated with adhesive on the matt side is placed on one or both sides of the glass cloth depending on whether the board is to be single or double sided. (i.e. the copper tracking on one side or both sides). The epoxy glass cloths and the copper are then heated and bonded together in a press. This completes the production of the laminate board.

Step 2 On receipt of laminate boards the PCB manufacturer carries out the following process as required by the electronics assembler. A sheet of plastic known as a photo resist is laid on top of the copper and on top of that is placed a piece of transparency film with the circuit pattern or artwork thereon. This is then exposed to ultra-violet light which causes hardening of the areas exposed by the ultra-violet light. The rest of the unexposed photo resist is developed away leaving the circuit pattern exposed on the copper cladding of the laminate. The next stage is to remove surplus copper from the laminate so that only the copper on the tracking pattern remains, this is achieved by application of an etch resist to the tracking pattern and thereafter etching of the surplus copper by means of immersion in an acid bath. PCBs may go through other processes in manufacture this depends on the specific purposes and requirements of the component manufacturer. After this process the boards are cut to size and the finished articles sent to the electronics assembler, (component manufacturer).

Step 3 The electronics assembler (example Sony) then fits components such as resisters, transformers etc., to the PCB and assembles the finished product to his specification.

The following tests have been carried out on Production PT35 in an attempt to identify the manufacturer of the PCB.

Resin Test On 8th February 1990, Mr. John French, Senior Chemist, Research Analysis Department, CIBA GEIGY Plc., Plastics Division, Duxford, Cambridgeshire, carried out a test in an attempt to identify the resin. Ciba Geigy Plc., are one of the worlds largest producers of resin for the PCB industry. Mr. French removed some small fragments from the piece of circuit board and analysed them on an FT-RI (Fourier Transform Infra Red) Spectrometer. This test showed that the laminate was manufactured using a Bisphenol A Epoxy Resin cured with Dicyandiamide which is very commonly used in the industry.

The reporting officers thereafter made contact with all companies in Western Europe, Israel, and East Germany, who manufacture copper clad laminates for the PCB industry and obtained samples of their laminates. On 8th March 1990, they returned to Ciba Geigy Plc., and supplied the following samples of laminates to Mr. French for analysis and comparison with Production PT35.

1.	LAMITEL	(Italy)
2.	PERSTORP	(Sweden)
3.	AISMALIBAR	(Spain)
4.	M.A.S.	(UK & Belgium)
5.	M.A.S.	(Italy)
6.	MICA AND MICANITE	(Ireland)
7.	FERROZELL	(West Germany)
8.	HULS TROISDORF	(Scotland)
9.	N.E.L.C.O.	(France)
10.	DITRON	(Italy)
11.	SEFOLAM	(Israel)
12.	PERMALI	(England)
13.	PIAD	(Italy)
14.	M.C. ELECTRONIC	(Austria)
15.	TRENCLAD	(Italy)
16.	METCLAD	(France)
17.	V.E.B.	(East Germany)
18.	A.E.G.	(West Germany)
19.	ISOLA	(Italy)
20.	ISOLA	(Scotland and West Germany)
21.	ISOLA	(Switzerland)
22.	DIELEKTRA	(West Germany)
23.	NORPLEX	(West Germany)

The results of the test carried out by Mr French were analysed on computer and two types of laminate, Sefolam and Ditron appear to give the closest match to Production PT35. It is worthy to point out at this stage that in the opinion of Mr French the condition of PT35 due to its exposure to extreme heat could have had an effect on the results of the analysis. Also, while the match to the two laminates, Sefolam and Ditron appear very close, this can only be treated as an indication and is in no way conclusive.

Laminate Test

On 14th February 1990 George Wheadon, Chief Technical Manager and Mr Paul Boyle, Laboratory Manager, New England Laminates Company, Skelmersdale, Lancashire, carried out an examination of the laminate of PT35. New England Laminates are one of the top manufacturers of copper clad laminates in the world. Mr Boyle removed a small cross section of PT35 which was examined under a microscope by Mr Wheadon and himself. Their findings were that the laminate is constructed with 9 layers of American standard 7628 glass cloth which is very commonly used in the industry. The copper used in the tracking is a standard thickness of 35 microns of 1 ounce weight. The copper on their visual examination appeared to have a protective lair of tin lead applied. The surface of the board had been brushed at some stage in its manufacture. On the opposite side of the board from the tracking pattern a solder mask had been applied. They were unable to determine positively whether the board was single or double sided but suggested that the solder mask on the reverse side from the tracks would indicate that it may be double sided.

Copper Test

On 15th February 1990, Mr Michael Whitehead, Chemical Process Manager, Yates Circuit Foil, Silloth, Carlisle, carried out an examination of the copper of PT35. This test required the removal of a small sample of copper from one of the tracks and its examination on a scanning electron microscope. This examination showed that the matt side topography of the copper foil was characteristic of the foil produced by the company Gould Electronics the main competitor to Yates in this industry.

On 7th March 1990, Mr Robert Lomer, Quality Assurance Manager, Gould Electronics Limited, Southampton, examined the copper sample removed by Yates Limited but was unable to reproduce the findings of Yates and concluded that the sample which had been mounted on an examination stud had come away at some stage and been lost. Mr Lomer removed a further sample of the copper track from PT35 and mounted it on a stud in a similar manner to that of the test carried out by Yates but again was unable to produce any results as the sample removed was unsuitable for examination.

Mr Lomer viewed photographs of the copper sample removed by Yates and the results of high magnification of that sample and was of the opinion that the matt side topography did show signs characteristic of the copper produced by Gould's and agreed that in all probability the copper was of their manufacture.

Metallurgy Test

On 2nd March 1990, Dr Rosemary Wilkinson, Strathclyde University, Glasgow, examined Production PT35 on a scanning electron microscope with EDAX (Energy Dispersive X-ray Analysis System). Her examination found that the two narrow tracks at the top of the circuit board showed the presence of copper and tin which is consistent with the copper being overlaid with a coating of tin. The pad area of the board showed the presence of lead, tin and copper which is consistent with a layer of tin lead solder overlying the previous structure of copper overlaid with tin. At the bottom left hand corner of the pad there is a lead rich area which has a diagonal marking which appears to be a section of a cylinder. It is possible, in her opinion, that this marking is a remnant of where wire was embedded in solder. There were certain areas on the pad which showed little or no lead. This could be explained by either manual application of solder not having covered these areas or by partial melting of the solder leaving these areas uncovered.

Solder Mask Test

On 9th March 1990, Mr Stephen Rawlings, Senior Analyst, Morton International Limited, Warrington, examined Production PT35. Morton International manufacture chemicals for the PCB industry in particular solder masks. Scrapings were removed from the underside of the board and examined on an FT-IR spectrometer. This test showed that the board had a two pack epoxy solder mask, green colour, applied to it. A solder mask is applied to protect the bare copper tracks during the soldering operation and prevents shorting between the tracks. There are three types of solder masks used in the industry as follows:-

1) Dry film application which is an adhesive backed sheet.

2) Liquid photo imagable.

3) Two pack epoxy which is screen printed.

The two pack epoxy solder mask which is applied to Production PT35 is the most commonly used type of solder mask used in the PCB industry. Once applied it is not possible to tell who manufactured the solder mask unless it is of a unique colour to the particular manufacturer. The green colour on PT35 is common to most solder masks of this type.

Mr Robert Linsdale, Technical Manager, Morton International Limited, further examined PT35 microscopically in an effort to establish whether the board had been of single or double sided.copper finish. On examination of the area where the solder mask had been scraped away he was of the opinion that the topography of this section of the board suggested that during manufacture copper had been etched from this area which would suggest that Production PT35 was part of a double sided board. He further examined the cross section of PT35 and measured the thickness of copper used and confirmed the thickness as 35 microns which is one ounce weight.

Evaluation of Information to Date - 16.3.90

Glass Cloth:

Though standard FR4 (fire resistant rating) glass cloth has been used in the manufacture of the laminate of Production PT35 the number of layers of glass cloth used may be a feature of importance. PT35 is constructed on 9 layers of glass cloth, the most commonly used method of production for this type of laminate board is to use 8 layers of glass cloth. This feature was identified by Mr George Wheadon, Chief Technical Manager, Nelco Laminates.

Epoxy Resin:

A feature of any interest in the manufacture of epoxy resin would be the chemical used in the curing process. In the case of Production PT35 the curing chemical is dicyandiamide. This is the most commonly used chemical for this purpose in the industry and does not assist in identification.

Copper Foil:

The two main producers worldwide of copper foil for the printed circuit board industry are the companies Yates and Gould. Each of these companies have manufacturing factories in the United Kingdom, Europe, USA and Japan. Between them these companies control 70% of the world market of copper foil. The process of manufacture carried out by both companies is similar but at the same time it is possible on microscopic examination of their products to differentiate between the two. This examination has been carried out at Yates factory at Silloth and the copper foil is identified as Gould's product. Unfortunately due to the size of their world wide market the value of this fact can only be one of interest. The weight of the copper foil in use is another factor which has been explored. The commonly used foil worldwide is one ounce weight. Less common is foil of half an ounce weight. In the case of Production PT35 the copper foil is one ounce weight, therefore again of no identifiable advantage.

Solder Mask:

As previously explained this solder mask is applied to the PCB prior to soldering of components to prevent solder flowing and causing short circuiting. (ie. surplus solder does not adhere but runs off solder mask). In the case of PT35 a solder mask is the green coloured application on the reverse side from the track pattern. On expert examination it is identified as two pack epoxy solder mask, screen print application, and is still the most commonly used solder mask in use worldwide. It therefore does not assist in identification of Production PT35. It is worthy to bear in mind that more modern methods of solder mask application are becoming more popular in the industry.

Tin Etch Resist:

Without exception it is the view of all experts involved in the PCB industry who have assisted with this enquiry that the tin application on the tracks of the circuit was by far the most interesting feature. The fact that pure tin rather than a tin/lead mixture has been used is very unusual.

This information comes after examination at Strathclyde University Department of Bio-Engineering. The information is recent and has not yet been explored to any degree. What has been learned to date is that the process is no longer carried out anywhere in the United Kingdom. Enquiries through contacts suggest that there are still some companies in West Germany using the process and names of these companies is awaited.

The consensus of opinion within the industry regarding this tin feature, is that it would tend to date the year of manufacture of PT35.

Further to this discovery, (i.e. pure tin on track) it is also established that on the large contact pad of the track, overlaid on the pure tin there has been an application of tin/lead. This suggests that a component or wire has been soldered to the circuit.

There are many lines of enquiry envisaged to further the knowledge of this feature of PT35 and these enquiries will commence on Monday 19th March by appointment at Digital Circuits Limited, Prestwick, when the thickness and method of application of the tin will be determined.

Test Samples Removed from PT35

In the course of carrying out tests as previously described it has been necessary for microscopic samples to be cut or scraped from Production PT35. This has at all times been carried out under the close control and scrutinisation of the reporting officers. A total of 5 particles have so far been removed as follows-

1) Tiny fragment from copper track - Yates, Silloth.
2) Tiny fragment from copper track - Gould, Southampton.
3) Particle of laminate - Ciba Geigy, Cambridgeshire.
4) Cross section cut - New England Laminate Company (NELCO), Skelmersdale.
5) Solder mask scraping - Dynachem Division, Morton International, Warrington.

In all cases the samples removed have produced photographs or spectra from analysis and these have been retained as productions. All productions labelled have been completed in relation to the productions and statement from persons carrying out the tests have been obtained.

Graphics, Photographs, Spectron Analysis

To record and act as an aide memoire it is intended with the assistance and guidance from sources who have been responsible for the analysis of PT35 to produce a document in book form to be viewed in conjunction with this report which will demonstrate the tests undertaken. This document will be be available in the near future.

Further Lines of Enquiry to be Considered

Underwriters Laboratories (UL), USA

This organisation appears to be a safety standard organisation in the United States similar to the British 'Kite Mark' system. Any reputable manufacturer of electrical components worldwide wishing to export to the USA must submit samples of their product to UL for safety approval (i.e. fire resistance properties, etc).

Contact has been made with this organisation at their Testing Department, Long Island, New York and information is that they have a 50/50 percent chance of identifying the laminate of Production PT35 if it were taken to them for examination. This possible identification would be achieved by comparison of the chemical components of PT35 against a library of information on laminates which is maintained by them.

Contact with UL has been temporarily suspended on the instructions of the Deputy Senior Investigating Officer after some discussion with FBI personnel.

It would require further discussion with technical representatives of UL, in the light of tests carried out on PT35 at Ciba Geigy Limited, to evaluate any further progress could be achieved. This matter will be re-acessed after senior level discussion between LICC and FBI.

It should be noted that on completion of tests carried out by UL it would required in the region of one month for them to compare these tests against their records as these records are not contained on computer. This assistance has been promised if an approach is made to the company from senior management level at LICC.

Assistance from FBI

Mr Tom Thurman, Special Agent, Explosives Laboratory, FBI, Washington has not been in contact with the reporting officers over the subject of PT35. In a recent telephone conversation to Detective Inspector Gilmour at LICC, Mr Thurman discussed Production PT35 and suggested that if taken to the FBI Laboratory Washington it was quite likely that personnel there could assist in its identification. SA Thurman has not been contacted by the reporting officers and will await instruction from the Senior Investigating Officer on this matter.

National Physics Laboratory (NPL)

Dr Colin Lea of the National Physics Laboratory when interviewed and allowed the opportunity to examine Production PT35 was doubtful that a successful identification could be achieved through chemical analysis. Dr Lea favoured the view that the publication of a suitable photograph of PT35 in journals and magazines in house to the PCB industry with a full accompanying description would achieve better results. Most important in Dr Lea's view to generate interest would be a reference in the insertion to the Lockerbie Air Disaster. Dr Lea is confident that if requested to do so he could have an article inserted in the journals and magazines of most value and most read in the industry.

Laminates

Tests carried out at Ciba Geigy Limited, Cambridge, on the chemical composition of epoxy resin of 23 samples obtained, show close matches from 2 laminates against PT35. These laminates are produced by:-

1) Sefolam - Israel.
2) Ditron - Italy.

Although as previously stated this test can only be considered a possible indication and not conclusive it is intended by the reporting officers to follow up this line of enquiry with other information as it is gathered.

Other Enquires

1 Exacta Circuits, Selkirk (PCB manufacturers). On 29th January 1990 a visit was made to Exacta Circuits where PT35 was discussed with Mr Ian Laing, Technical Director and Mr Colin Gass, Technical Manager of this company.

2 RS Components Limited, Corby, Northampton. RS Components is a major electrical component suppliers company with a turnover of 11,000 electrical components per day with a cash turnover one million pounds per day. On 13th February 1990, a visit was made to this company and PT35 was shown to certain members of the technical and product support team. Certain observations and suggestions were put forward as to the possible identity and function of the circuit on the board but no definite information was received.

3 Du Pont, UK (Solder Masks). On 16th February 1990 contact was made with Mr Roy Hollaway of this Company. It was learned at this time that Du Pont do not have any proper laboratory facilities in the UK but they were able to give some helpful information and advice.

4 Prestwick Circuits, Ayr (PCB manufacturers). On 6th March 1990 a visit was made to Prestwick Circuits where Production PT35 was discussed with senior management and technicians. Excellent co-operation and advice was recieved. The conclusions of those present were that the board had been professionally manufactured but not to a high standard and using dated technology. The best line of enquiry in their opinion was that the tin which was used as an etch resist was uncommon as was the nine layers of glass cloth used in the construction of the laminate and these were the best avenues to pursue.

5 British Telecom (Quality Approval Department). Contact has been made on several occasions with Mr Len Pillenger, British Telecom. Mr Pillenger had a valuable library of information and a stock of sample laminate boards from several manufacturing companies. On request Mr Pillenger supplied a number of samples of laminate boards which were valuable in comparison at the tests carried out Ciba Geigy.

6 Clock Manufacturers with United Kingdom. Contact was made with several clock manufacturers within the United Kingdom to establish the type of product being manufactured and the type of circuit boards which would be contained in any clocks produced. It was learned at this time that there are no companies in the United Kingdom actually manufacturing clocks - all are imported from abroad.

7 British Standards Institute. On 20th February 1990, contact was made with Mr Mike Gower of the British Standards Institute. Mr Gower was unable to assist in any way with our enquiries.

8 International Tin Research Institute, Uxbridge. Contact was made with Mr Denham of the International Tin Research Institute on 13th March 1990. Mr Denham stated that after the tin had been plated onto a board there is nothing that can be analysed in the tin which would be worthwhile. As far as measuring the depth of the tin on the tracks he would be unable to carry out this work as he did not possess the equipment necessary. He did however recommend contact

with a company who had a Fischer scope X-ray which could complete this work without causing any destruction to Production PT35.

9 Printed Circuit Board Federation, London. On 13th March 1990, contact was made with Mr Haken of the Printed Circuit Board Federation. Mr Haken knew of no list or information available on companies using tin as an etch resist. He did however suggest publishing all available information on Production PT35 in their monthly news letter and that or their equivalent federations in Europe and the USA (BIPC European Interconnection Printed Circuit and the IPC Institute for Interconnecting and Packaging Electronic Circuits which are widely read in the printed circuit board industry.

Conclusion

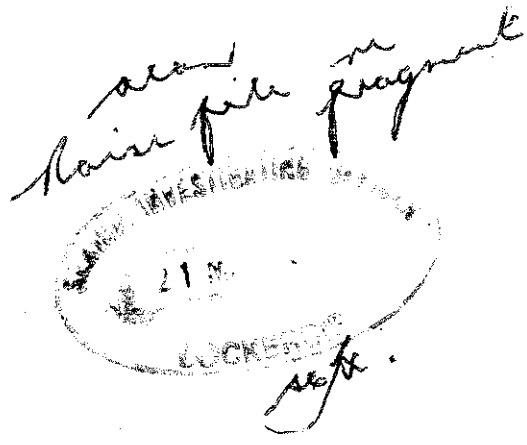
Since commencing enquiry to identify Production PT35 information and assistance has been gathered from many sources as shown. In some case in the course of carrying out comprehensive tests, companies have given full laboratory facilities for full working days with many technicians involved.

Prior to any visit the sensitivity and integrity of the enquiry had been impressed on the contact person and to date this has not been breached.

At all times the reporting officers have met and been received with sincere interest, understanding and willingness to assist and in all cases received an invitation to return if further information or clarification of information is required.

It is respectfully requested that at some future date a letter of appreciation may be transmitted from the Senior Investigating Officer to a limited number of persons who have been especially helpful in this enquiry.

Detective Inspector Detective Constable



FORT HALSTEAD, 30 MARCH 2000

ALLEN FERADAY, Retired Forensic Scientist

Address: c/o DERA Fort Halstead, Sevenoaks, Kent

Age: 62 years (D.O.B. 23/12/37)

STATES

I retired as Head of the Forensic Explosives Laboratory (FEL) at DERA Fort Halstead in December 1997. I had been Head of the FEL since Tom Hayes left in August 1989. I joined the predecessor of FEL, the Explosives Research and Development Establishment at Waltham Abbey, in 1955. In my 40 years of work at ERDE and FEL I was involved in many forensic examinations of explosions, including terrorist incidents. My experience included all aspects of forensic examination but my expertise and interest was in electronic devices such as timers for bombs.

I am satisfied that, although it has been over ten years since the work was carried out, that it will be possible to determine the source of the productions raised by Tom Hayes and myself at FEL. We examined many thousands of pieces of debris that had been recovered from the crash scene, including pieces of aircraft, baggage and clothing.

Both Tom Hayes and myself made contemporaneous notes during our examinations. These notes allow us to say with certainty which productions were raised at FEL and from which pieces of debris they were extracted. The normal method of referencing such productions would have been to use the initials of the person who found it and a sequential number. E.g. TSH346

However, to assist the police with their records of the evidence, we were asked to use the prefix PT followed by a number. E.g. PT35

I am shown

PROD.NO. PT90: File

and

PROD.NO. PT91: File

These are the working files that Tom Hayes and I kept. They were made contemporaneously with our examinations. This is the standard practise in FEL. In these files we recorded descriptions of the debris we examined and our conclusions. It is possible to examine the notes relating to a piece of debris and determine whether anything was extracted from it. For example, page 51 of Tom Hayes' notes shows that he examined a piece of debris with the reference PI995 on 12 May 1989.

His notes reveal that he found a number of foreign pieces of debris embedded in PI995 and extracted them to make up PT35 and PT2.

In fact, I remember when this was done. Although Tom Hayes was carrying out the examination, I think that he invited me in to see the pieces embedded in PI995 before he removed them. He knew that I would be interested in what he had found. I therefore remember that PT2 and PT35 were extracted from PI995. This is consistent with what he has written in his notes and will apply to all the pieces of debris extracted and raised as productions at FEL, even though I may not remember finding them. I am satisfied that my notes are accurate in this regard.

I have been asked about the classification of

LABEL NO. PI148: Piece of clothing

in

PROD.NO. DM141: Report
And
Books of photographs

It is described in the second category of clothing but appears from its description to meet the criteria for the first category. Tom Hayes established the criteria and I did not feel comfortable using them because of items like this. The more precise the criteria, the greater the number of items which will fall on the borderline, such as this piece.

It is so difficult to be precise about such classifications. I would not have adopted such strict criteria for the clothing. It is possible that the fragments of debris removed form this piece of clothing were trapped in it, even though the piece of clothing was not in the suitcase containing the IED. The presence of the fragments does not establish this by itself.

I am aware of an incident during the early 1990's when minute traces of the chemical RDX were found in our laboratory. They had escaped from a leaking air pipe. They were only detected because our standards are so strict. Because of the risk of cross-contamination, a thorough independent investigation was carried out by scientists from outwith the Ministry of Defence. Their clear conclusion was that this incident had not presented any risk to previous work and had not caused any cross-contamination.

TRUTH JTL/PD

NOTE

THIS PRECOGNITION WAS LIMITED TO THE PROVENENCE OF THE PT PRODUCITONS AND THE POINTS RAISED BY CROWN COUNSEL ABOUT THE CLASSIFICATION OF PI148.

FERADAY WAS DISMISSIVE OF HAVING LINDA JONES LOOK AT THIS POINT BECAUSE SHE WAS NOT INVOLVED IN THE EXAMIANTION OF THE CLOTHING

MEMORANDUM

To S/EC's

From Allen Feinday

Date 8/8/89.

Tel

Your Ref

Our Ref

Subject Walter Korsgaard. FAA.

Cliff

In drafting a note to the FAA regarding the activities of Walt Korsgaard you may care to consider some of the following points.

1. We (RARDE) are grateful to the FAA for allowing us to participate in the most meaningful First series of explosive tests held at Indian Head in April 89.

2. These first five tests confirmed some of our observations and measurements gained during our examination of all of the Lockerbie debris. The tests further confirmed that our estimates of the size and position of the explosive charge within the baggage pod were approximately correct.

3. Subsequent trials conducted by Mr Korsgaard in July at Atlantic City did little to add to our knowledge of the explosive device parameters gained during the earlier test. Virtually no cognizance of the earlier results appears to have been taken by Korsgaard in constructing the second series of the tests. The first series

were not even documented by him. However, valuable information regarding the interaction of the prime sintcase with its surrounding neighbours was gained during these second series of tests, and even more could have been gained if time had been allowed to document this important aspect of our work.

4. An approach was made to the Lockerbie investigators through D/Ch/Insp: Bell at the completion of the Atlantic City trials as to the attitude of Lockerbie and RARDE concerning possible further explosive tests to be carried out by Korsgaard on an actual 747 aircraft.

5. It is our view that in general any further explosive trials by Korsgaard concerning the Lockerbie case are unnecessary and ill advised, and as such should be discouraged. Such trials could easily be misconstrued by any defense counsel as implying some doubts concerning the results of the earlier trials, and as such could be disadvantageously exploited by counsel.

6. If a future trial were planned on a pressurized 747 to substantiate the first series results and the Lockerbie scientific results, then such a trial may be of some limited value to the Lockerbie investigation. Such a trial would need to be carefully planned taking full account of the previous results and with the full involvement of Lockerbie, RARDE and the FBI, all of whom

MEMORANDUM

To	From
Date	Tel
Your Ref	Our Ref

Subject W.K. (continued)

7. Failure to take account of the scientific findings to date and of the results of the first series of tests, renders any future explosive tests of little value. Such tests would be unnecessary, undesirable and possibly even destructive to the general course of the investigation and its legal aims. Furthermore, there are possible international repercussions concerning any future explosive tests.

8. It would be foolish and detrimental to the case to allow any errant defense lawyer to gain succour from any future explosive tests apparently designed purely to enhance an opinion as to the charge weight, against all previous test results and the scientific findings to date.

9. As a personal note — I do urge in the strongest possible terms that Korsgaard be stopped from carrying out any further tests in connection with the Lockerbie investigation. If, however, he does continue with his trials then I am equally adamant that we must be present to document and interpret his results. AMF

Also enclosed - part of note prepared by Bell and myself for Ch/Supt ORR

RARDE FORM 173