Typed [illegible] dated 6/3/90.

INTERNAL MEMORANDUM

From:
Det. Insp. Williamson,
L.I.C.C.
3.9.90.

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.

Photographing of Production PT 35

At an early stage in the investigation to determine the physical composition and establish the manufacturing processes used in the production of the fragment PT 35 it was repeatedly opined by all technical persons who assisted in making preliminary assessments that in order to further their examinations test samples would require to be removed from the fragment for analysis thus changing its physical appearance.

Prior to any removal of scrapings, test samples and cross sections from PT 35 it was necessary that good quality photographs be taken of the fragment to record its original shape and condition to allow future comparison to be made with any similar printed circuit board or further fragments should they be recovered. The photographing of Production PT35 was carried out on 12th February 1990 under laboratory conditions by the Identification Bureau at Strathclyde Police Headquarters, Glasgow.

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.

Tin Test

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.

Further to the discovery (i.e. pure tin on tracks and pad) it is also established that on the large contact pad of the circuit the pure tin has been overlaid with an application of tin/lead which suggests that the component or wire has been soldered to this part of the circuit.

In furtherance of this information an examination to establish the thickness of the tin applied was carried out by Digital Equipment (Scotland) Limited using a Fischer scope XRF and measurements were taken at various points. These tests showed that the tin varied in depth from 1.41 microns to 4.57 microns.

Enquiry has been made with numerous companies throughout the United Kingdom involved in the printed circuit board manufacture, in an effort to learn more on the use of tin and the reason for its application to the tracks but these enquiries have so far proved negative, there being no companies known in the United Kingdom involved in the manufacture of printed circuit boards who continue to use pure tin in the manner that tin has been applied to Production PT 35.

Evaluation of Information

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.

Test Samples Removed from PT 35

In the course of carrying out tests as previously described it has been necessary for samples to be cut or scraped from Production PT 35. This has at all times been carried out under the close control and scrutinization of the reporting officers. A total of six samples have so far been removed from the production as follows:-

1. DP10 - tiny fragment from copper track - Yates, Silloth.

2. DP15 - tiny fragment from copper track - Gould, Southampton.

3. DP12 - particle of laminate - Ciba Geigy, Cambridgeshire.

4. DP11 - cross section cut - New England Laminate Company (NELCO), Skelmersdale.

5. DP16 - solder mask scraping - Dyna Chem Division, Morton International, Warrington.

6. DP31 - cross section cut - Siemans AG, Munich, West Germany.

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

Removal of Cross Section Production DP 31 FROM PT 35

The most significant test sample removed from Production PT 35 is a cross section cut which includes part of both conductor tracks and part of the main "soldering land". This sample was removed on 27th April 1990, at the technical laboratory of Seimens AG, Munich, FRG, by a technician under the control of Deputy Director Hans Brüsamle. The cut was made in the presence of Mr. Brüsamle and D.I. Williamson. (Note: The technician who carried out the cutting of the fragment was unaware of its origin or the reason for cutting and no statement was taken from him). The cross section was given the Production No. DP 31. The reason for the removal of this cross section was to allow further information to be gained on,

a) the method and applilcation of pure tin to the conductors.

b) the further application of tin/lead to the land.

to confirm the weight of copper.

d) to confirm if the PCB were single or double sided.

Due to the time limitation on carrying out these examinations at Seimens AG and further on the advice of Mr. Brüsamle that the same tests could be carried out in the United Kingdom the full test examination of cross section DP 31 did not proceed at Seimens AG.

Further Evaluation Production PT35

On 23rd May 1990, Production PT 35 together with cross section cuts Productions DP 11 and DP 31 were again microscopically examined at Ferranti International, Oldham, by the Chief Chemist Mr. Allan Worroll. On completion of his examination Mr. Worroll gave a written final assessment on his conclusions as to the physical description and material construction of the fragment. This description is shown as follows:

PT 35 - Printed Circuit Board

Examination by Senior Chemist at Ferranti International Computer Systems, England, resulted in the preparation of the following technical description of the fragment.

1. The circuit board is single sided - there is no evidence of any through hole plate connections.

2. The board is one ounce copper clad FR4 epoxy glass laminate, 1.6 mm thick.

   9 layered glass cloth, 7628 type.

   (9 layered material popular in Italy).

3. Solder mask has been applied to both side of the board. Solder mask appears to be a wet epoxy based type, either screen printed or more likely brushed on to the board.

Reason for coating both sides of a single sided board is a mystery.

4. The small tracks are nominally 0.010 inches (10 thou), 250 microns, with 0.018 inch (450 microns) spacing between the tracks.

5. The tracks are coated with pure tin, probably from an electroless tin solution, presumably to aid solderability.

6. Normal electronic grade solder 60-65% tin (remainder lead) has been used to make a solder connection to the pad.

7. The etch profile on the copper pad and the tracks suggest that the circuit could have been 'home made', although the machined radius of the board suggest a commercial machining operation.

Further examination on specific features have established the following points relative to the piece of circuit board:-

Epoxy Resin

The glass cloth laminate is manufactured using a Bisphenol A epoxy resin cured with Dicyandiamide.

Copper Foil

The matt side topography has the characteristic of a foil produced by the company Goulds Electronics.

lder Mask

Solder mask is two pack epoxy resin which is green in colour, either screen printed or brushed onto the board.

Further Information

Mr. Worroll has identified that there is some evidence, i.e. a long scratch like mark across the big pad to suggest that thin insulated wire could have been soldered to the pad. The 'scratch' appears too uniform to be a scratch and has the part profile of a wire having been laid across the pad when partial fusion of the tin occurred leaving the impression of a thin wire lead.

Secondary Ion Mass Spectrometry (SIMS) Test

After preparation of cross section Production DP 31 (cut from PT 35) during which Mr. Worrell removed by means of grinding the solder mask to allow analysis of the back side, the sample DP 31 was subjected to Sims test at THE CENTRE FOR SURFACE AND MATERIAL ANALYSIS AT THE UNIVERSITY OF MANCHESTER.

THE PURPOSE OF ANALYSIS

1. To record surface specific mass spectra from the conductor tracks on the board to determine whether the surface chemistry consisted of pure tin (which was known to be present) or tin containing any other species.

2. To compare the surface chemistry of the underside of the board with that of two similar "standard" boards to determine if it were made from either of these materials. The two other boards were produced by the companies Sefolam and Ditron, these boards being the closest matches to Production PT 35 in tests carried out by Ceiba Geigy plc., on 8th February 1990. The test was conducted by Dr. David Johnstone, BSC., PhD., Application Scientist, a full document now listed as Production DP 36 describes the method of Sims test and the results produced by Dr. Johnstone. The comparative test of DP 31 (Part PT 35) with the boards Sefolam and Ditron showed that PT 35 had not been made from either of these two materials.

Photographs and 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 analyses of PT 35 to produce a document in book form to be viewed in conjunction with this report which will demonstrate the tests undertaken.

Other Enquiries

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 received. 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.