22 Aug 2013

Serendra Explosion Incident

Final Report – Part One

The Incident, Its Origin and Immediate Cause

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CONTENTS

1. INTRODUCTION

At about 20:00 (8:00pm) local time on 31 May 2013 an explosion occurred at Tower BA, 2 Serendra, Bonifacio Global City, Taguig City, Republic of Philippines which resulted in the deaths of four persons. Three of these were in a passing vehicle which was struck by a section of concrete wall propelled from the building. The fourth was an occupant of Unit 501B who suffered burns and was conveyed to hospital, where he died on 4 July 2013.

An initial investigation by the Philippines National Police (PNP) eliminated a terrorist bombing as the cause of the explosion. The investigation was then continued by the Bureau of Fire Protection (BFP) and the Inter-Agency Anti-Arson Task Force (IATF).

Kroll Advisory Solutions Asia (Kroll) was subsequently commissioned by the Department of Interior and Local Government (DILG) to assist with the investigation, and contracted Mr James Munday to provide specialist expertise. Mr Munday is a forensic science consultant specialising in the investigation of fires, explosions and related incidents. A summary of his qualifications and experience forms Appendix A to this report. He has investigated and given expert evidence concerning numerous matters having features in common with this incident.

The on-site investigation in Taguig City was completed by Mr Munday and Mr Ilya Umanskiy of Kroll from 10 July to 16 July 2013. It involved a number of tasks at 2 Serendra and other relevant locations. These included a detailed site inspection, examination of items removed from the incident scene to laboratories, in-person questioning of some witnesses and preparation of question plans for others, inspection of the liquefied petroleum gas (LPG) vapour supply system operated by Bonifacio Gas Corporation and participation in formal briefings.

After leaving the Philippines, further tasks included collation and interpretation of the physical and documentary evidence, engineering calculations, application of codes and standards, validation of methods and findings of the investigative teams and providing recommendations for consideration by DILG.

Copies of all documentation, photographs, video recordings and other materials obtained by the BFP and IATF have been made available. A full list of all the material used in the preparation of this report appears at Appendix B, while Appendix C contains copies of inspection notes and sketches. Voice recordings made by the Kroll team during the investigation have been copied to CD and supplied separately.

Verbal information was given to the Kroll team by the IATF personnel and laboratory staff throughout the investigation as requested. Kroll wishes to place on record its appreciation of the open and frank way in which information has been shared throughout the investigation, and especially thanks to the BFP-IATF personnel who assisted with informal interpretation of witness statements into English. Valuable assistance was also given by representatives of Ayala Land Inc.

2. EXECUTIVE SUMMARY

1. The explosion at 2 Serendra originated inside Unit 501B. No high explosive or other condensed phase explosive material (e.g. gunpowder) was involved.

2. The explosion resulted from the pressure wave of a high speed deflagration, caused by the ignition of escaped liquefied petroleum gas (LPG) vapour mixed with air.

3. The escape of gas took place from the open end of a flexible hose intended to supply the gas range in the kitchen of Unit 501B.

4. Physical evidence indicates that the gas range was removed and replaced to facilitate the recent renovations to the Unit and that the hose was not re-attached to the range correctly. This was denied by the contractors responsible for the work in the Unit.

5. The most probable ignition source for the gas-air mixture was operation of the electrical main switch beside the front door to the Unit, as Mr San Juan was about to leave for the evening.

6. There was no direct involvement of the fixed LPG installation within the building, and no fault or defect was found in it which directly contributed to the incident.

3. THE INCIDENT, ITS ORIGIN AND IMMEDIATE CAUSE

3.1 Scene Examinations by PNP, BFP and IATF

1. From an initial appraisal of the structural damage, it was determined at an early stage that the most severe structural damage was to Unit 501B located at the north-east corner of Tower BA. The explosion was centred on that unit, with overpressure damage indicators in the rest of the structure pointing back towards this location.

2. In the initial stages of the post-blast investigation, inspection of 501B was carried out by SPD with the use of K9 units. Subsequent to searching for unoperated devices, a joint examination by SPD and SOCO units concluded that there was no indication of improvised explosive devices (intact or operated) and no blast damage indicative of high explosive. This was supported by laboratory analysis showing no explosive residues on samples taken from the building.

3. Further work conducted by SOCO and other agencies including DOST found that the probable mechanism involved a gas explosion, most probably involving LPG vapour.

4. Inspection and partial reconstruction of items found outside the unit, having been propelled by the explosion pressure or fallen during the structural collapse, showed that Unit 501B had been fitted with a cooking range which included gas burners. This was supplied from the unit's local gas meter by a length of iron pipe, known as a stub-out, terminating in a shut-off valve from which had become detached a length of flexible hose.

5. Detailed examinations and measurements of the building, especially Unit 501B, were carried out by BFP and IATF personnel. A reconstruction was made of the kitchen base cabinet where the sink was located, based on the measurements of the remaining parts, and compared with those fitted in other units. This indicated that the original cabinet had been shortened at its north end by approximately 23mm (9"), most probably to accommodate the range in the north-east corner of the kitchen following modifications made to the north end of the kitchen during the renovation. Pre-renovation plans and photographs show a full-length cabinet.

6. IATF led by FSSUPT Jaudian considered explosion force vectors, superficial burning and other directional indicators within Unit 501B to determine the epicentre of the explosion. This was concluded to be immediately inside the front door, in a semi-circle of approximately 1m radius. Within that area were electrical switches capable of providing an ignition source for a gas-air mixture.

7. The source of the LPG vapour was determined by IATF to be the supply hose for the cooking range, which had either become disconnected or had not been correctly replaced at the end of the renovation work.

3.2 Laboratory Findings

1. NBI laboratory analysis confirmed that no explosive residues or ignitable liquid traces were present on materials recovered from Unit 501B.

2. Examination of electrical equipment from the unit showed that the gas sensor from the kitchen had no internal fault condition and the plug prongs were not bent.

3. The main electrical breaker panel from the unit showed no internal fault conditions and the main switch located beside the front door was in the OFF position at the time of the explosion.

4. DOST laboratory examinations of the range, hose, stub-out and meter indicated that there were no over-pressure failures prior to the explosion which would have released vapour. In addition, meters from other units which had been displaced during the incident were not leaking or faulty prior to it.

5. The leak detector from the ground floor meter cupboard at Unit 101B was intact but switched OFF when found. On testing, it was found to be inoperative.

6. DOST analysis of paint found on the flexible hose established that it was the same as that on the kitchen wall.

7. A rapid assessment PID method used to test the ethyl mercaptan concentration in the LPG vapour at the Bonifacio Gas plant and at the Brazil Restaurant showed a level of $1.1x10^{-8}$ ppm.

3.3 Scene and Laboratory Inspections by Kroll

1. On-site examinations took place on 10-13 July 2013 with inspections of items previously removed at IATF offices on 13 July and DOST laboratory on 16 July. The Bonifacio Gas Corporation tank and vaporiser facility was also inspected on 13 July, and a visit was made to St Luke's Medical Centre on 16 July for a briefing from Dr Aro.

2. The site examination took place in the basement of the complex, interior of Towers BA and BB, exterior of Tower C and the surrounding open areas. It was noted that there was no Level 4 in the Towers for cultural reasons, the levels being designated G, 2, 3, 5, 6, 7, 8 in BA and up to 10 in BB. There was also no unit 4 or 7 on each level, with the units on the north side designated 01-05 (BA) and 09 (BB) and those on the south side designated 02, 06 (BA), 08 and 10 (BB).

3. External inspection took place immediately after briefing and arrival on site on 10 July. The debris field surrounding tower BA had largely been cleared prior to this date but the location of various items was pointed out and confirmed from photographs and the SOCO sketch plans.

4. Some items of interest remained. These included the entry intercom from 501B, which was located on a grassed area to the north-east of tower BA, and a section of aluminium tube bearing Ms Cayton's name which was on a grassed area to the north-west of the tower. This was later identified as the interior of a roller blind from the north-west bedroom (master bedroom). The locations of these items, especially the intercom, were indicative of an explosion epicentre in or beyond the south-east quadrant of Unit 501B.

5. Among the debris in the grassed area to the north of tower BA was some partially melted black synthetic cloth which appeared to be part of a shirt sleeve. The cuff was fastened and intact, which indicated that it was not being worn at the time and had probably been hanging on a rail

when struck by the expanding flame front. Other fabric remains were also found which appeared to originate from bedding, the location of which corresponded to projection from the master bedroom.

6. There were marks and adhering debris on the south wall of the adjacent block in Section A, together with impact damage to fittings including windows and balcony rails. The height and distance of these indicated a powerful explosion centred on Unit 501B or travelling through it from the south side of Tower BA. However the lesser damage to Unit 502B and the south side of the Tower, together with the limited debris strike on the function room, indicated that the epicentre was not in 502B or the corridor.

7. Items projected from the building had been removed from the roadway and car park to the east of Tower BA soon after the incident for safety and evidence recovery reasons. Again these were identified from photographs and plans.

8. Based on the external physical evidence it was estimated that a pressure above 30kPa (approximately 35psi) was generated inside Unit 501B. This corresponds with the IATF calculations of the force necessary to displace the east wall panel into the roadway, which were seen later.

9. An overpressure of this magnitude arising from a gas- or vapour-air explosion is strongly indicative of the mixture igniting when close to stoichiometric ratio (see Technical Information below). This was supported by the lack of post-explosion fire damage visible from outside the building.

10. On 11 July the LPG vapour supply installation within section B of 2 Serendra was inspected from the Bonifacio Gas intake at basement 1 level through the mother meter, second stage regulators, main meter and distribution system to the riser and dropper pipes in towers BA and BB. The sub-meters for the individual units were fed from the dropper pipes. Schematic diagrams of this system provided by the Ayala representative are shown in Appendix D.

11. In the basement meter room there were three shut-off valves for the incoming supply. One of these was an earthquake sensor valve, one was connected to a gas detector and the third was a manually operated by-pass valve. There were operating instructions for the earthquake valve displayed on the wall but none for the leak detector valve.

12. The gas detector was positioned at low level on the adjacent wall and hard-wired to the local lighting circuit junction box, so as to be permanently energised. However it was equipped with a slide switch on its front panel and therefore could be manually rendered inoperative.

13. The valve to which the detector was electrically connected was a ‘normal-on’ type, which would be closed electrically on receiving a signal from the detector. This differs from a ‘normal-off’ or ‘fail-safe’ valve, which is held open electrically against a spring or gravity closer and shuts automatically if the sensor detects gas and interrupts the supply. The latter will also close in the event of electrical power loss, whereas the type fitted in basement 1 would stay open.

Figure 1 – shut-off valves in basement meter room

Figure 2 – gas detector in basement meter room, showing manual slide switch on front panel

14. From the basement meter room, normal iron pipe of various diameters conveyed the vapour to the surrounding buildings. There were numerous isolating valves and earthquake joints within the installation which appeared to be of good quality, and nothing unusual or inherently unsafe was observed.

15. From basement 1, the BA Tower riser passed through a vertical pipe chase or duct behind the meters outside Units 101B-801B and entered the roof space above the east wall of 801B. At each floor level, the dropper and sub-meter for the unit was located in front of the riser. It was noted that this chase was continuous from ground floor to roof, with no firestopping or other sealing where it passed between levels.

16. In the roof, the riser became a horizontal distribution pipe with droppers passing down beside flats 101B to 801B and between 103B-105B and 803B-805B on the north side of the corridor. Further horizontal pipes led above the 8th floor corridor ceiling to corresponding droppers serving units on the south side of the Tower. The dropper chases were also continuous from roof to ground floor with no seals or firestops.

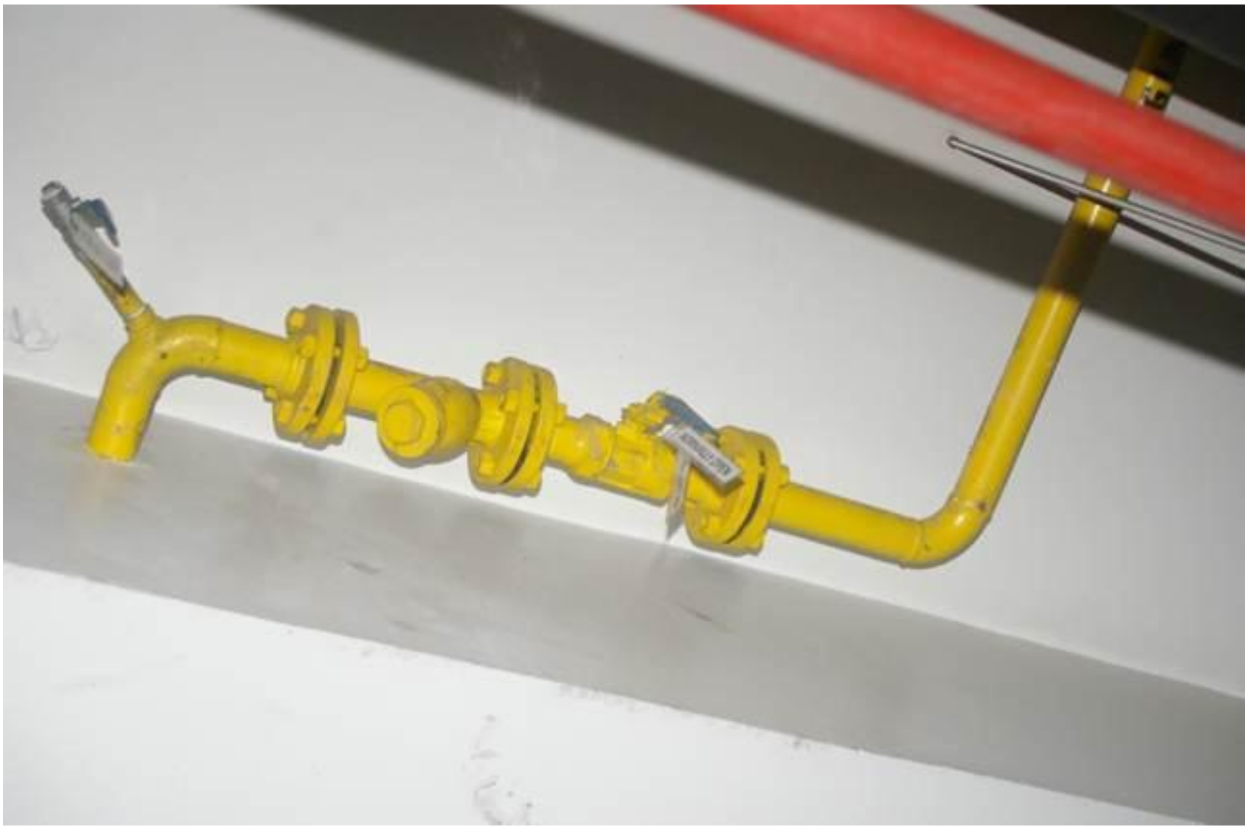


Figure 3 – Tower BA riser penetrating basement 1 ceiling to ground floor outside Unit 101B

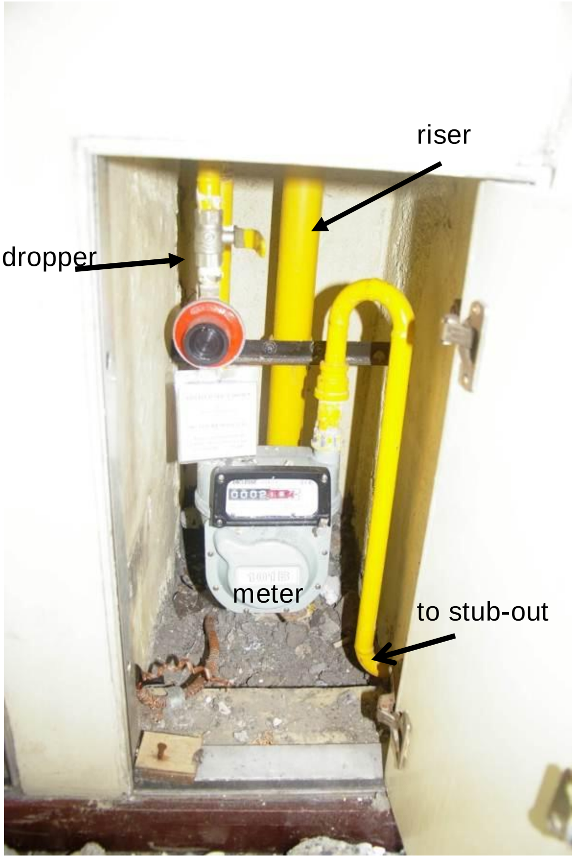


Figure 4 – Unit 101B meter cupboard

Figure 5 – Unit 201B meter cupboard, showing open duct rising from ground floor level

17. At the time of inspection, the meter cupboard outside 101B contained no gas detector although its flexible wiring sheath was present. This detector was removed for testing after the incident and found to have been switched OFF. When powered up by connection to a 220V supply, it was inoperative. It is understood that the detector was connected to the alarm panel and provided an audible warning. There was no associated shut-off valve on the riser.

18. The 11 July inspection continued into the residential and common areas of Towers BA and BB. All levels of Tower BA and corresponding levels of Tower BB had suffered some degree of overpressure damage. Full details of the relevant observations are contained in the notes at Appendix C and the CD accompanying this report.

19. In brief, there were indications of both positive and negative pressure wave damage which had travelled via three main routes. The first and largest of these was the internal corridors and hallways of the building, off which opened the individual units and other common areas as well as maintenance enclosures.

20. There was external venting from the open ends of the internal corridor at each level, with further external venting at the open south end of the link corridor between Towers BA and BB. Much of the excess pressure had dissipated to atmosphere at these openings, which had further limited the internal structural damage. Venting locations to atmosphere from Tower BA are marked with arrows in figure 6 below.

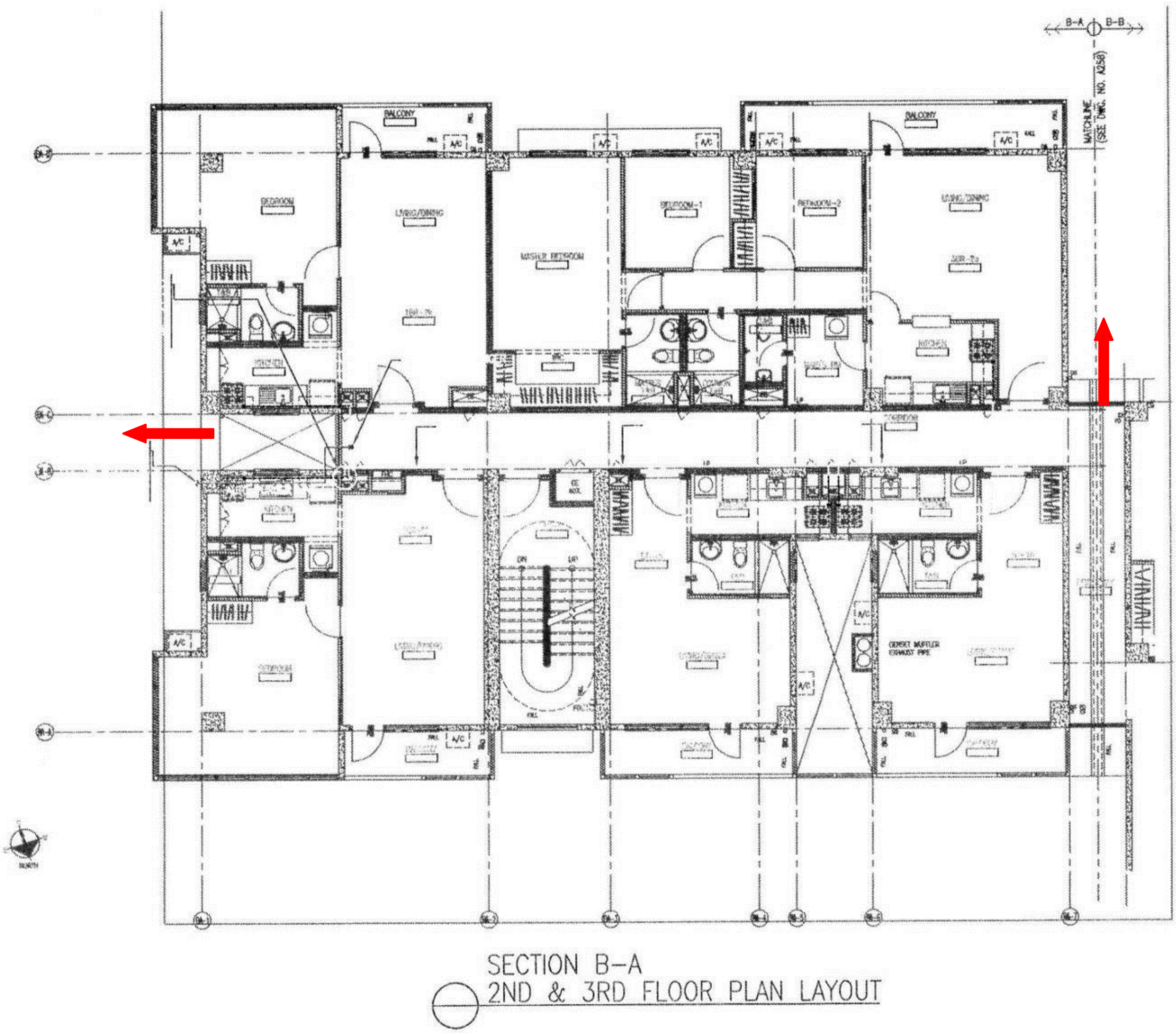


Figure 6 – example floor plan showing Tower BA layout above ground floor,
copied from Makati Development Corporation plans
Red arrows show venting to atmosphere
(Not to scale – for illustration only)

21. As a result of the overpressure in the corridors, many of the units had suffered failure of their entry doors and disturbance or breakage of the internal contents. Hosereel cabinet glass doors had failed on all levels of both Towers. There were also some structural effects such as cracked walls and broken windows inside units on Level 5, closer to the source of the explosion.

Figure 7 – Tower B, Level 3 corridor,
view E from link corridor

Figure 8 – Tower BA Level 6 corridor,
view E from link corridor

22. The second route of travel for the pressure wave was via the elevator shafts, with distortion to the doors at Levels G and 5 and the cars jammed inside. The effect of the pressure wave at the moment of impact on the elevator cars is visible in the CCTV recordings. The white smoke-like substance seen in those images and reported by several eye-witnesses was probably composed largely of dust particles.

Figure 9 – ground floor elevator doors

Figure 10 – level 5 elevator doors

23. The third major route of pressure wave dispersal was via service ducts, voids and chases in the building structure. This was exacerbated by the presence of continuous chases from ground to roof level for the gas risers and droppers previously mentioned, and utilities rooms at each level of the Towers. Electrical and plumbing services also passed between ground and Level 8 or roof space with limited or no sealing of the spaces around the pipes and conduits at each level. As a result, water and LPG meter cabinet doors and utility room doors had been forced open outwards on levels above and below Level 5.

24. There was communication between these vertical service spaces and the horizontal cavities between the suspended ceilings of the corridors and the concrete slabs above. This enabled the pressure to spread through the ceiling cavities, opening service hatches and displacing the ceiling structure itself in places.

25. At Level 5 of Tower BA, there was a different pattern of damage. The utilities cabinet doors were pushed in and the ceiling had both lifted and then collapsed. At the link corridor there was upward displacement of the earthquake joint cover on Level 6 above, combined with downward displacement and twisting of the vertical cable tray in the ceiling space.

26. In Units 301 and 601, directly below and above 501B respectively, the damage and displacement was greater than in other units on those levels. The hallway door of Unit 301B was propelled inwards approximately half-way across the unit, its north balcony door pushed outwards and a glazed internal door to the kitchen broken from the west side. There was damage to the ceiling caused by downward pressure from 501B. The door to Unit 601B was also propelled part-way into the living room, the north wall windows had failed outwards, the kitchen ceiling had been forced upward before falling down, and several internal fittings were displaced.

27. All of the pressure damage patterns were indicative of a pressure wave spreading from Unit 501B through the rest of the building. In addition, there were indicators of a rapidly moving flame front exposure to some surfaces outside that unit, which indicated that the combustible vapour-air mixture extended at least into the Level 5 corridor and possibly beyond.

28. Among these indicators were scorching to the exposed edges of plasterboard backing paper, slightly melted and scorched fabrics and plastics in units on Levels 3 and 6. The farthest locations from 501B in which transient flame damage was found were Unit 706B, where some scorched paper towel was lying on the floor, and Unit 201B where curtains at the north window were singed. Although the paper in 706B could have been transferred in from outside during the post-incident activities, the curtains in 201B had remained in position.

Figure 11 – scorched paper towel on floor in Unit 706B

29. There was an area of more prolonged burning outside Unit 306B where a small fire had occurred inside the LPG meter cupboard. This was consistent with displacement of the meter and piping by the overpressure causing a gas escape and ignition. Localised flaming then continued until the building supply was shut off at approximately 20:10-20:15. Remains of the meters from this cabinet and that of 506B above were recovered from there by IATF and later examined at the NBI laboratory.

Figure 12 – Unit 306B meter cupboard

30. There was more severe damage to the structure and fixtures on Level 5. The BB Tower corridor was down near the link corridor and the doors to Units 508-510 had failed. There was no significant internal disturbance to these units.

31. The elevator lobby ceiling had failed and the doors were distorted, with the north window projected outwards. The link corridor ceiling was completely down, with significant distortion to the frame and cable tray and displacement of the Level 6 earthquake joint cover plates above. Sliding doors from the link corridor to the BA Tower corridor had been forced out onto the link corridor floor, from where they were reconstructed in position by the IATF.

32. Within Level 5 of Tower BA, the damage was more severe progressively to the east. On the south side of the corridor, Unit 506 ceiling was partially down, its balcony door pushed out to the

south, and the east bedroom wall cracked at the top. Unit 502 was more badly damaged, with its door disintegrated, considerable structural damage to the south wall and displacement of the window and cracks to the internal and external walls.

Figure 13 – Level 5 link corridor ceiling and cable tray, view South-East

Figure 14 – Level 6 link corridor, view South showing lifted steel plates

Figure 15 – Tower BA Level 5 utilities cabinet and fire exit

Figure 16 – Tower BA Level 5 fire exit door projected into stairwell

33. On the north side of the corridor, both Units 503 and 505 had doors forced in, with considerable internal disruption, north walls and windows displaced outwards and ceiling failures. The utilities enclosure doors between 503 and the fire exit stairs were pushed inwards from the corridor, and the heavy steel fire exit door was projected into the stairwell.

34. The corridor ceiling had failed completely with increasing damage to the suspension frame and concealed utilities approaching the eastern end. Directly outside Unit 501, the water and sprinkler pipes were disrupted and the fire alarm system was compromised.

35. There was burning inside the meter cupboard for Unit 506 similar to but slightly more severe than that at 306. This was also consistent with flaring of escaping gas during the period between the explosion and the shutting off of the main supply.

36. There was also burning and smokestaining to an area of cracked wall panel above and to the east of the meter cupboard, where a polymer sealing strip in the wall construction was exposed and partially burnt. It appeared unlikely that this strip had been ignited directly by a rapidly moving and transient flame contact.

37. On looking inside the meter cupboard, it was apparent that numerous gaps and channels were present in the block wall and mortar construction between the meter cupboard interior and the sealing strip. It was considered most probable that heat and smoke transfer took place through these gaps and ignited the exposed sealing strip while the escaping gas was burning.

Figure 17 – meter cupboard outside Unit 506B

Figure 18 – duct above 506B meter cupboard, open to roof level,
showing gaps in block and mortar construction; North face to left of image

Figure 19 – burning at cracked wall above and East from 506B meter cupboard

38. The burning at the meter cupboards for 306B and 506B did not appear to be due to separate and deliberate ignitions preceding or contemporaneous with the explosion. It was considered much more probable that disruption of the equipment inside by the pressure wave led to some localised leakage of LPG vapour which was ignited by the passing flame front.

39. The most severe structural damage involved Unit 501B. Both the north and east external wall panels had been lost outwards, together with their windows and other fittings. The kitchen windows and part of the south wall were projected across the light well against the facing wall of Unit 502 before collapsing to the ground at the bottom of the light well with some of the kitchen contents.

40. The remainder of the south wall was displaced outwards across the corridor towards the north wall of Unit 502. The front door was disintegrated and had been reassembled by IATF to show the extent of the damage.

41. The east wall of Unit 501 was one of the building shear walls, constructed from approximately 400mm thick reinforced concrete, and had withstood the explosive forces along with the building corner columns. The horizontal concrete beams along the north, east and south sides of Unit 501 remained in place but with some cracking.

42. The tiled floor slab showed cracks and possible displacement, which would explain the damage to the ceiling of 301 beneath. A small gap was apparent between the beams and the ceiling slab, which may have been due to lifting by the internal overpressure but could also have been due to lack of sealant application during construction. Similar areas were noted in other locations which had been exposed to less explosive force.

43. Unit 501B had been recently remodelled from its original one-bedroom layout to a two-bedroom configuration. This involved construction of a metal stud and plasterboard wall, introduction of an additional doorway and removal of a washing machine alcove to the west of the bathroom. The washing machine was relocated to the east end of the kitchen, where an enclosure was built to conceal it.

44. The following illustration broadly depicts the changes made to the unit, although not precisely to scale. The room marked 'new bedroom' was referred to by the designers as master bedroom and the other as guest bedroom. They are designated bedrooms 1 and 2 in this report.

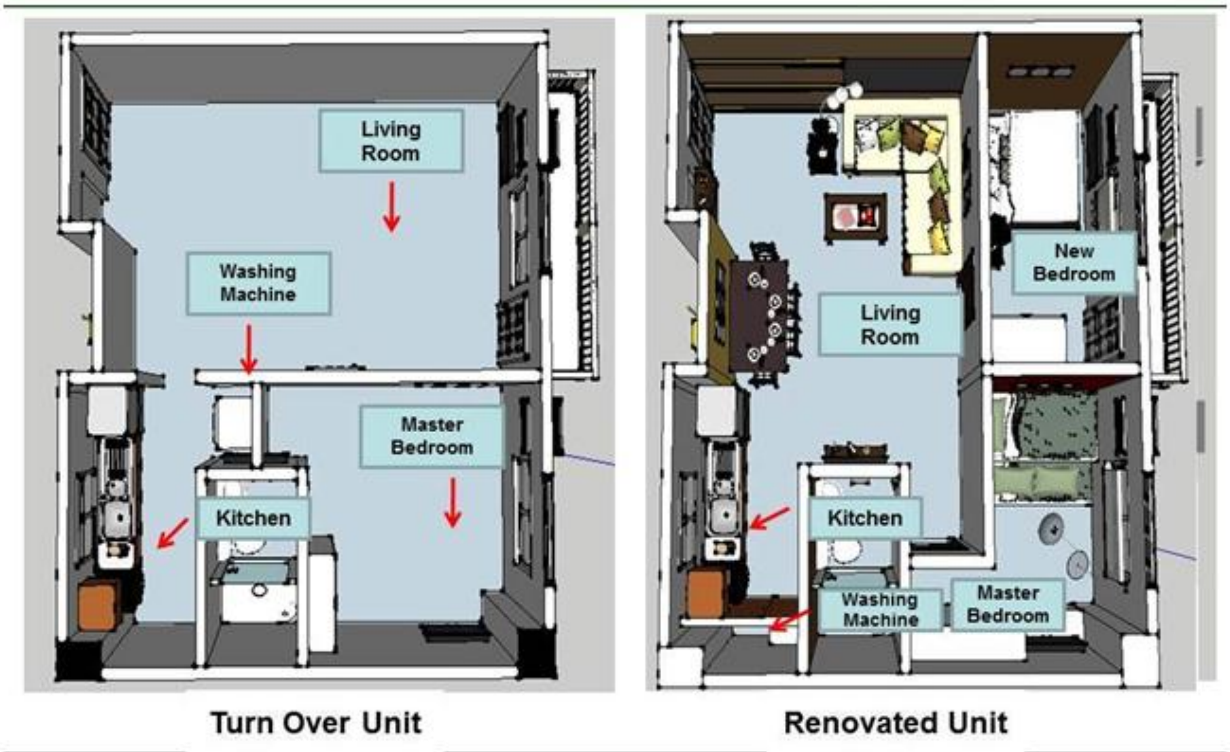


Figure 20 – comparison of unit layout before and after renovation, diagram courtesy Ayala and IATF
(Not to scale – for illustration only)

45. The internal stud wall to bedroom 1had been destroyed by the explosion, with the frame displaced northwards. The stud wall between bedrooms 1 and 2 had been largely projected from the building. The upper west wall of the bathroom had largely fallen to the west but this appeared to have resulted from negative pressure, after weakening by an initial force application in an eastward direction.

46. Other negative pressure indicators were present including a section of the displaced south wall which was bent back to the north, movement of furnishings and movement of the short partition wall section to the east of bedroom 1 doorway.

47. The north and south bathroom block walls had failed outwards in both directions. This reflected the lack of restraint provided by the short steel pins inserted into the ceiling slab, when exposed to positive overpressure entering the small room via the doorway.

48. The furnishings of Unit 501 had been recovered and replaced in position by IATF. These showed widespread transient heat and flame damage from floor level to a height of approximately 0.8m, indicative of flame front development through a cloud of denser-than-air vapour mixture. In the absence of any volatile flammable liquid, the only viable explanation for this was the involvement of the LPG vapour.

49. A small area of more prolonged burning occurred in the kitchen shown in SOCO photographs involved some cardboard or paper packaging and produced a small smoke plume. The location and duration of this burning was consistent with it being caused by flaring of escaping gas from the stub-out valve until the supply was shut off.

Figure 21 – heat and flame damage to bedding in bedroom 1

Figure 22 – heat damage to bed in bedroom 2;

note top mattress position reversed, more severe heat damage should be at South end

Figure 23 – melting and scorching to front faces of sofa cushions, scatter cushions penetrated

50. The pressure vectors were plotted on a floor plan to assist in locating the explosion epicentre. Figure 24 below shows a simplified version of the vector plot for clarity.

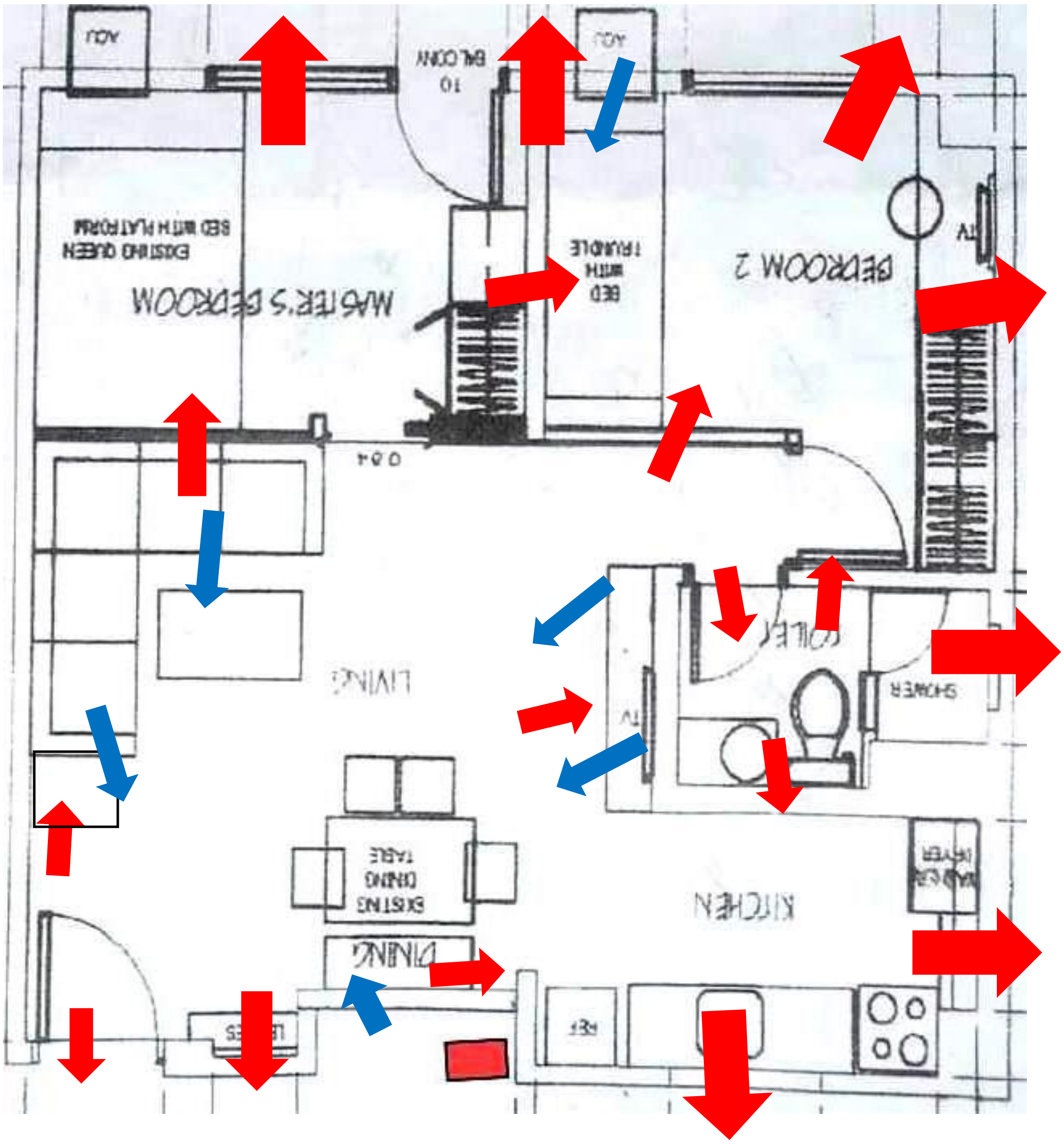


Figure 24 – simplified pressure vector plot of Unit 501B, superimposed on C+G Design Studio concept plan

Key: positive pressure

negative pressure

(Not to scale – for illustration only)

51. On 13 July at the IATF office, items previously examined by DOST were inspected. These comprised the gas meter and associated pipework, stub-out pipe with shut-off valve, range from Unit 501B, and a shoe believed to have fallen from Mr San Juan while he was being helped to an ambulance.

52. The gas meter was removed complete with the supply pipe, manual ball valve and regulator from the cupboard outside 501B. It bore evidence identification labels confirming this information. The pipework had been unscrewed at its threaded joints.

53. The ball valve was in the ON position, with the handle parallel to the pipe, and the meter and regulator were intact with no observable heat or impact damage. The regulator was marked as shown below. The meter reading showed 39.797 cubic metres, as previously recorded by SOCO personnel. The supply pipe was labelled ‘tested no leak 6/22/10’.

Figure 25 – gas meter and pipes from 501B

Figure 26 – regulator markings

54. The stub-out pipe was approximately 2.5m long, with two shallow bends and a double elbow connection at the kitchen end (furthest from the meter). Attached to the second elbow was an impact damaged electrical shut-off valve with a chromed outlet, into which was screwed a brass flexible hose fitting.

Figure 27 – stub-out pipe

Figure 28 – stub-out elbow coupling to damaged shut-off valve

55. The fitting was sheared off with a fractured surface, indicating a violent impact or distortion but not repeated flexing. On the chromed surface were abrasions and adhering material consistent with an impact. There was a metal clamp and bracket attached to the kitchen end of the pipe, of the type used to hold it to a wall or the inside of a cabinet. The bracket was also broken with a fractured surface.

Figure 29 – fractured end of flexible hose fitting

Figure 30 – pipe clamp and bracket

56. The fittings were installed with white PTFE thread tape, protruding ends of which were shrivelled and scorched by transient flame contact. This was the visually the same type of tape as that used in the meter cupboard.

Figure 31 – close view of heat-affected thread tape

57. The range was a black-finished 'La Germania' model SL6031 60BT, serial number 0403-A-0588. It was equipped with three gas hob burners, one electric hotplate, and an electric oven-grill combination. The oven showed no indication of having been used and the hob drip tray was very clean. The range gave the impression of being either newly installed or very little used prior to the incident.

58. There was an electrical input at the rear which terminated in a two-pin plug with a separate earth tail. The prongs of the plug were distorted, suggesting they were pulled laterally from the socket. The range had not been hard-wired into the kitchen supply circuit as is common for appliances of this type in many countries. Other electrical connections at the rear supplied the hotplate, oven and grill heating elements and the oven fan. Some of the spade terminals were displaced but there was no indication of electrical arcing or melting at any of the contact faces.

Figure 32 – kitchen range front

Figure 33 – kitchen range rear

59. The gas burner and oven-grill controls were all in the OFF position, as shown by the spindle flats where two of the control knobs were missing. The electric hotplate control was in the ON-LO position with no indication that this was due to impact. However it could have been moved during retrieval; the position of this knob at the time of discovery is not clear in the SOCO-NBI photographs.

60. At the rear of the range, the gas inlet fitting was intact and undamaged by bending or impact. It was located behind the rear right of the hob (viewed from the front of the appliance) and designed to accept a flexible hose with clamp fitting.

Figure 34 – gas range inlet fitting

61. A grey casual shoe was examined, and found to have melting and scorching damage to the lace area and the ankle padding. The damage was indicative of brief exposure to a flame or radiant heat source which surrounded the shoe.

62. On 16 July, the flexible hose was inspected at DOST. It was a 1.19m length of black fibre-reinforced rubber pressure hose, open at one end and slightly elliptical in cross section with a diameter between 9.5mm and 10.5mm. This corresponded to a nominal 10mm hose.

63. At the other end, the hose was firmly clamped around a broken brass fitting which corresponded to the remains in the stub-out valve outlet (see Figure 29).

Figure 35 – flexible hose in packaging

Figure 36 – open end of hose

Figure 37 – clamped end of hose

Figure 38 – remains of brass fitting in clamped end

64. Approximately 50mm from the open end was a drip mark resembling white paint. The directional nature of this, perpendicular to the pipe axis, indicated that it had been deposited while the pipe was horizontal. When attached to the range, this section of hose would be close to vertical.

65. Approximately 300mm from the open end was a screw clamp which had been taped in position when recovered. The screw fitting was loose, such that the clamp would slide on the hose unless taped.

Figure 39 – paint drip near open end of hose

Figure 40 – loose clamp 300mm from open end

3.4 Background and Witness Information

1. Prior to the incident, Unit 501B had undergone a renovation with a concept design by C+G Design Studio, contracted to RM Ladrido Construction Services for detailed design and building.

2. In summary, the design required the construction of partition walls and doorways to form two bedrooms as previously described, the relocation of the washing machine to the east end of the kitchen and associated demolition of original walls at the west end of the bathroom, and repositioning of the furnishings to suit the new room layouts. Painting and associated decorative works were included in the requirements.

3. The designers and contractors initially denied any modification to the existing kitchen fixtures and fittings, and any disconnection or significant movement of the gas supply pipe and flexible hose to the range.

4. One of the contractors described painting the kitchen walls and said that he moved the range a short distance to do so. This distance was not specified.

5. In subsequent interviews described in the final IATF report pp 57-59, 75-76, 78 & 81, it was established that the gas range had been removed from the kitchen to the sala in order to modify the kitchen cabinets and was returned to its position at a later stage of the renovation.

6. Following the renovation, the owner Ms Cayton visited the unit and agreed a punch list for remediation. Subsequently Mr Cuizon and Mr Dumaguing re-attended before the key was handed to Mrs Mendez.

7. Prior to this, an engineer's inspection request was refused because no as-built plans were available from Ladrido or C+G. Arrangements had already been made for Mr San Juan to stay at the unit from 31 May 2013.

8. On Mr San Juan's arrival he was conveyed to the unit by Mr and Mrs Mendez, Mrs Ochoa and her daughter Arlean. They arrived just before 07:00 on 31 May, when the water and LPG supplies to the unit were turned on in the meter cupboards outside. Mr Mendez operated the LPG ball valve but it is not specified if the meter cupboard was locked or open when he arrived.

9. After about 30-40 minutes everyone left the unit. During that period nothing unusual was noticed, such as sounds or odours. In the early afternoon Mr San Juan returned to the unit accompanied by a security guard who helped him carry groceries from the basement car park.

10. During the day, electrical maintenance was in progress which limited the power supply to each of the units. Air conditioning systems were inoperative until at least 18:00 but there was a pedestal fan in the unit. Mr San Juan complained by telephone to his friends of being hot and 'feeling suffocated'.

11. Mrs Ochoa arrived at the ground floor reception area to collect Mr San Juan at approximately 19:15, having previously sent a text message. When he failed to appear, a security guard went to Unit 501B but was unable to get a reply. Mrs Ochoa sat in her car trying to contact Mr San Juan by phone for some time and then went to the unit with security staff at about 19:50.

12. After a great deal of knocking and ringing, Mr San Juan opened the door a little way and had a conversation with Mrs Ochoa. Security Guard Aresola described the light inside the unit as off and Security Guard Falcasantos said it was dim; Falcasantos also noticed a pedestal fan operating inside the room and recalled an odour of fresh paint. The security staff left and Mrs Ochoa returned to the drop-off area at approximately 19:56. During the whole of this period, no-one had noticed an odour of LPG in or around the unit and the Level 5 corridor.

13. Mrs Ochoa described her conversation with Mr San Juan as follows: *'When I reached the apartment, I tried to knock and ring the bell many times. Finally he opened the door, peeked outside, and said "sorry, I fell asleep"*. She reminded him that their restaurant reservation was at 19:00 and it was already nearly 20:00. He said he would finish his shower, get dressed and meet Ms. Ochoa downstairs.' She also smelled new paint while at the door.

14. At approximately 19:59, the explosion occurred. Security personnel went to investigate and other people came from outside the building to assist. Several residents of Towers BA and BB were evacuated from their units.

15. An odour resembling that usually found in LPG was reported by Ms Kangleon when leaving her Unit 301B along the corridor past 306B, and by Mr Bernas when fighting the fire at the 506B meter cupboard. Both of these reports were after the explosion occurred and from persons close to the damaged meters where burning occurred.

16. Further enquiries made of the available witnesses did not reveal anyone who smelled LPG in the building at any time on the day of the incident or in the preceding months.

17. After the explosion and before going to hospital, Mr San Juan said to Mrs Ochoa words to the effect of '*I opened the door knob then I heard an explosion, I was thrown to the floor and felt electrocuted'.*

18. Descriptions of Mr San Juan's injuries at the scene and during hospital treatment indicated that he suffered extensive burns around almost the whole of his body. Much of his shirt was burnt off but his pants remained in place until removed at hospital. The clothing could not be located for inspection and may have been sent for biohazard disposal.

19. Dr Aro described superficial partial thickness burns to Mr San Juan's torso, back, legs, face and hands. He had deep partial thickness burns to his right lower back, both calves, left hand and full thickness burns to the right ankle. There was sparing to both outer upper thighs, probably coincident with protection by pants pockets and contents.

20. There was no indication in any of the witness statements that Mr San Juan was a cigarette smoker or that he was in any way inclined to self-harm.

21. Further witness statements were seen which referred to issues such as the building construction, management, energy supplies etc. They will be summarised in their respective sections for clarity.

3.5 **Technical Information on LPG and Explosions**

1. Liquefied Petroleum Gas (LPG) is a mixture of two main components, butane and propane. The ratio of the components differs among suppliers and markets, largely dependent on local climate and availability issues. In this case, it is reported by Mr Palomar and Mr Silang that the mixture was effectively 70% butane and 30% propane. Commercial grade LPG also has traces of other hydrocarbon components at concentrations negligible in the circumstances of this case.

2. The difference between LPG and other fuel gases (such as methane or coal gas) is that it can be liquefied by compression at atmospheric temperatures. This makes it convenient and economical to transport, either in small portable cylinders such as 4kg and 9kg domestic sizes, or in bulk tankers to refill larger static cylinders and tanks supplying one or more adjacent buildings.

3. In these cases, the LPG supplied to the end user is in liquid form and it turns to vapour when the cylinder valve is opened to release the pressure. The energy needed to evaporate the liquid comes from the environment which is why the outside of the container feels cold to the touch when in use.

4. An alternative supply method, and the one which was used at 2 Serendra, involves bulk vaporisation of the liquid at a single remote location followed by transport of the vapour through a fixed pipe system to a number of end users. Because much more liquid is being evaporated, additional energy has to be supplied in the form of an evaporator. These are usually heated by hot water, although some are direct-fired by LPG burners.

5. The system used by Bonifacio Gas Corporation involves the bulk supply of liquid LPG by tanker to a storage facility in Taguig City, where it undergoes conversion to vapour in a set of hot water vaporisers. From there, vapour is piped at regulated pressure underground to client buildings where a further pressure reduction takes place by secondary regulators. The vapour then flows through the client's internal pipe installations through further metering and pressure reductions as needed to end-user outlets.

Figure 41 – Bonifacio Gas Corporation vaporiser plant, Taguig City

6. Systems such as this are in common use globally, with some of the largest modern installations in recent constructions in India and other Asian countries (see Appendix E for some examples). Historically, piped LPG vapour systems have been used widely in the USA, Canada, Australia, New Zealand and some European countries.

7. LPG vapour is colourless, odourless, non-toxic but potentially suffocating by oxygen exclusion, and denser than air. This means that escaping LPG vapour tends to flow to the lowest available level and form a layer there, mixed with air entrained at the point of escape. Because it is readily ignitable and therefore hazardous, an odorant additive is mixed with the LPG so as to alert users or passers-by to the presence of an escape before it reaches dangerous concentrations.

8. Like all fuel gases and vapours, butane and propane can only be ignited when mixed with air in the correct proportions. There is a range of concentrations in which ignition can occur, between the lower flammability limit LFL and the upper flammability limit UFL. These are also known as

explosion limits, LEL and UEL, because ignition of the gas or vapour mixed with air can lead to an explosion.

9. The flammability range for butane is 1.9-8.5% and for propane is 2.1-10.1%. Butane vapour has a density of 2.5kg/m^3 and propane 1.9kg/m^3. For practical purposes, LPG vapour of the reported composition can be treated as a single gas with explosive limits of 2-10% and a density of 2.3kg/m^3. These figures were used for the calculations in this case.[1]

10. The maximum pressure produced by the burning of a gas-or vapour-air mixture is directly related to the flame speed through the mixture. This is in turn highly dependent on the concentration. Close to the upper and lower limits, the pressure is at its lowest and reaches a maximum close to the so-called 'stoichiometric' ratio. This is also known as the 'perfect mixture', where the amount of vapour is exactly right to burn in the amount of air available with none left over. In the case of the LPG mixture above, the stoichiometric ratio is approximately 4.5% vapour in air.

11. On ignition, the flame front expands spherically outwards with a wave of compressed, hot combustion gases and air preceding it. This produces the pressure which causes the explosion damage. Objects encountered by the flame front break up the spherical structure and cause turbulence, which accelerates the burning. A video recording depicting this process in an experimental setting forms part of Appendix F.

12. The type of explosion resulting is known as a 'vented confined explosion', where parts of the structure fail in order of weakness to vent the pressure. If the vent area is insufficient the pressure continues to build until another structural element fails, and so on. This can result in multiple peak pressures, each higher than the previous one.

[1] www.engineeringtoolbox.com

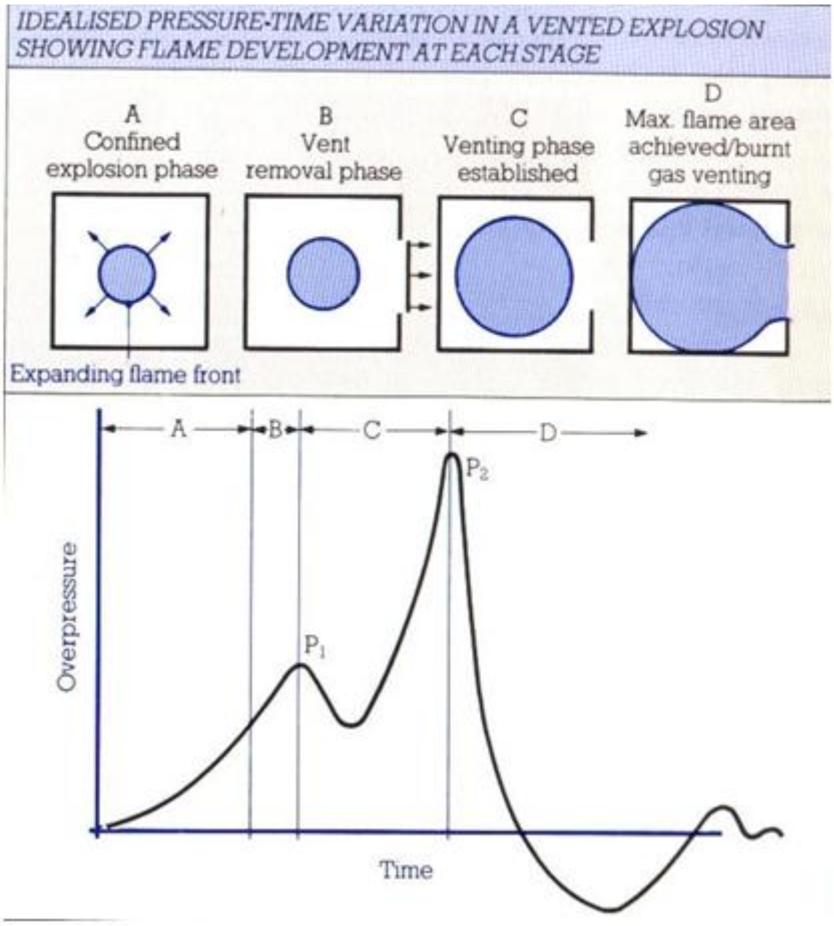


Figure 42 - simplified stages of a vented confined gas explosion[2]

13. The extent and severity of the damage caused at 2 Serendra indicated that the mixture was at or close to 4.5% when ignited. However stratification (layering) effects caused by the density of the LPG vapour mean that it would initially be more concentrated close to the floor and less concentrated higher up in the room, to a level approximately 0.9-1.0m above floor level. Immediately after ignition, turbulence caused by the expanding flame front would effectively mix the vapour and air throughout the whole enclosure.

14. Another phenomenon which usually occurs is the escape of unburnt vapour-air mixture from the initial compartment (e.g. Unit 501B) to a second area (e.g. the corridor) prior to ignition, by flow through existing spaces such as under and around doors. This enables the flame front to continue expanding and burning fresh fuel outside the compartment of origin. The presence of the pressure wave compresses the fuel-air mixture ahead of the flame front, which causes more rapid burning and an escalation in maximum pressure.

15. In addition, the expanding pressure wave in the first compartment can pressurise and force vapour-air mixture out ahead of the flame front, where it travels through connecting areas or into

[2] From Harris RJ, Investigation and control of gas explosions in buildings and heating plant.

the atmosphere. The following flame front ignites the mixture, leading to fire and explosion effects remote from the point of origin. In this case, transient flame effects were found up to two stories from Unit 501B and pressure effects throughout the whole building.

3.6 Calculation

1. The following assumptions were made in order to calculate the parameters of this explosion:

   a. Duration of gas escape at Unit 501B 07:00-20:15 (allowing time after explosion for gas shut off to building) = 13.25 hours

   b. Total volume of gas escaping = final meter reading 39.797 – initial meter reading (28 May) 4.576 = 35.221m^3

   c. Hence flow rate = 35.221/13.25 = 2.7m^3/hr (F)

   d. Hence volume of gas escaped prior to 20:00 = 35.221 – 0.66 = 34.56m^3 (Q)

   e. Overall internal volume of Unit 501B = 7.4x6.65x2.7m = 132.8m^3

   f. Less 10% fixtures, fittings, furniture = 119.5m^3 (V)

   g. But effective volume V* of unit limited to depth of vapour-air layer, approx. 1.0m

   h. 7.4x6.65x1.0 = 49.2m3, less 10% fixtures, fittings, furniture = 44.3m^3 (V*)

   i. Supply pressure downstream of meter = 0.4psi = 2.76kPa = 27.6mbar

   j. Dynamic viscosity of LPG vapour = 8 x 10^{-6} Pas at 1 bar

   k. Equations and sources used for calculation methods are listed in Appendix F

2. The first calculation was carried out prior to inspection of the stub-out pipe and flexible hose, in order to predict the size of the escape orifice needed to supply the known flow rate of vapour at the known supply pressure. For a flow rate of 2.6m^3/hr at 0.4psi, an aperture of 9.5mm diameter was predicted. At a flow rate of 2.8m^3/hr, the aperture needed was 11mm diameter. From this, the predicted escape orifice had a diameter of 10mm within method error.

3. Other calculations were carried out to explore whether a cracked iron pipe or penetration of the flexible hose could be responsible. Each indicated a much lower flow rate than was known to be the case.

4. On measurement of the flexible hose, it was found to be a 10mm nominal bore which corresponded with the calculation.

5. The next calculation concerned the vapour concentration in the unit prior to the explosion. The effective room volume V* was 44.3m^3 and the gas escape volume Q was 34.6 m^3, giving a concentration of 34.5/44.3 = 78%. This would be far too high to ignite and therefore much of the escaping gas must have left the unit via doors and windows prior to 20:00.

6. Taking the UEL of 10%, assuming perfect mixing the maximum gas volume in the effective unit volume would have been 0.1x44.3 m^3 = 4.43 m^3. Thus (34.56-4.43) = 30.13m^3 of vapour was lost outside the unit during the period of escape. Some of this would have leaked to atmosphere via

the windows but a proportion would have passed around the door, entered the corridor and drifted through the building.

7. In practice, there would not have been perfect mixing. The quantity of vapour in the unit would have been somewhat greater due to the formation of a density gradient, with a higher concentration near the floor. As long as the concentration near the ignition source was within flammability limits, the turbulence resulting from ignition would rapidly disperse all the vapour within the whole compartment volume. Under these circumstances, it is acceptable to use the whole unit volume V rather than V* in the calculations, if it is assumed that the overall concentration was close to 4.5%.

8. To achieve a mean concentration of 4.5% in the whole unit would require 0.045x119.5 = 5.4 m^3 of vapour, leaving 29.1 m^3 to be dispersed outside the unit. Thus from both calculations approximately 30 m^3 of LPG vapour escaped from unit 501B during the period of escape.

9. Alternative calculations were carried out to determine the vapour flow rate from the hose at the given supply pressure using the measured pipe length from the meter, orifice diameter and standard correction factors for fittings. The results were between 2.6 and 2.8 m^3/hr, confirming the initial time-based method and the concentration figures.

10. IATF initially used an alternative calculation method based on separate assessments for the butane and propane flammability limits and concentrations. Using a figure of 30% butane, it was calculated that the mean concentration assuming perfect mixing in the whole unit volume was 7.97%, i.e. within the explosive limits. This figure was then used to calculate the explosive forces.

11. The calculation was repeated in the final IATF report using corrected gas proportions of

12. 70% butane and 30% propane. Under these circumstances the figure of approximately 8% vapour in air applies to the propane concentration rather than the butane.

13. This concentration is at the high end of the flammability range and would therefore be expected to cause less overpressure but more burning. However the very rich butane component, approximately 18% in air, would not initially ignite due to excess fuel. Once additional ventilation was available, due to structural failure, the excess vapour would continue to burn until consumed over a period of several seconds or longer. This would be expected to cause much more severe heat and flame damage than that observed within Unit 501B. In addition, witnesses would be expected to report a large fireball of significant duration from the unit. No such statements have been seen by Kroll

14. The IATF reasoning on this method of calculation is therefore questionable and it is considered that the alternative method of considering the vapour mixture as a single effective fuel source is more valid.

15. It is therefore necessary to determine if only 5.4m^3 of LPG vapour would produce sufficient force to cause the structural damage observed. Using the same energy release calculation as the IATF report, taken from NFPA921, but substituting 3.78m^3 of butane and 1.62m^3 of propane results in a total combustion energy inside the unit of 606.5MJ.

16. Since the energy required to propel the east wall panel was calculated as 1.4MJ, it is confirmed that the structural damage suffered by Unit 501B would result from the explosive combustion of

as little as 5.4m^3 of LPG vapour within the unit, together with an unquantified amount in the corridor outside.

4. EVALUATION

1. In order to determine the most probable sequence of events, it is necessary to consider all of the above physical and witness evidence together.

2. The first question to be considered is how the LPG vapour came to escape into Unit 501B. When Mr Mendez opened the meter valve at approximately 07:00 on 31 May, gas began to flow into the unit at approximately 2.7m^3/hr from the 10mm diameter open end of the hose. For some reason, explored further in Part Two of this report, the escape was not detected either in the morning, later that day when Mr San Juan re-entered the unit or in the evening when Mrs Ochoa and the security guards visited him at approximately 19:49.

3. Because of the computed flow rate available from a 10mm hose, it would not be possible for the escape to have commenced as late as 13:00. Therefore a deliberate act by Mr San Juan on returning to the unit in the afternoon can be eliminated.

4. It is clear from the physical evidence that the flexible hose to the range was either disconnected or loosely clamped at the range inlet for it to have separated in the way observed, with its clamp unscrewed and partly down the hose length. The possibility was considered that a surge of gas when the meter valve was opened caused a poorly clamped hose to slide off the range inlet.

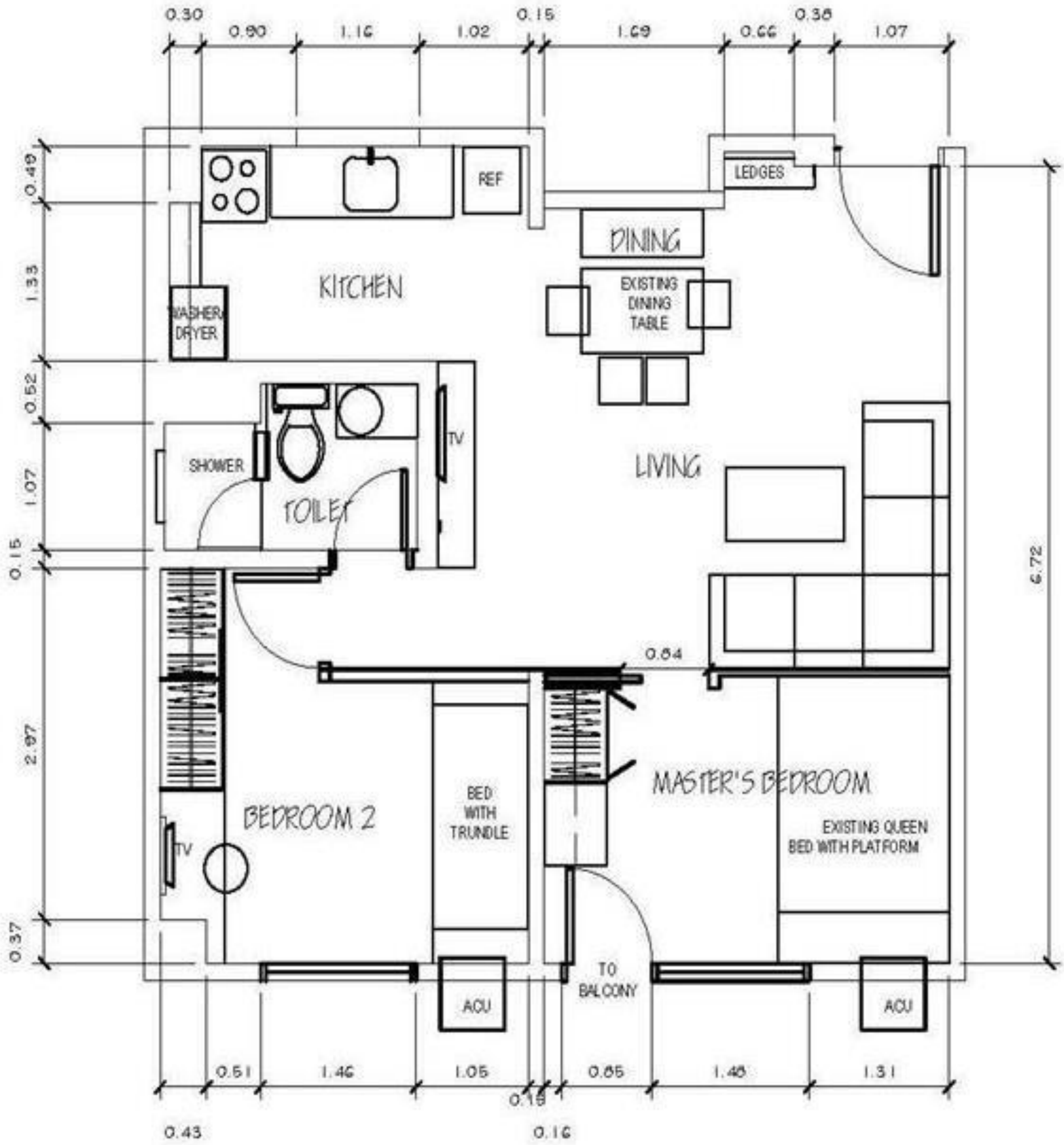
5. However this would not explain the paint drip orientation which showed that the range end of the hose had been horizontal, and thus probably lying on the floor, when the wall was being painted. Although it may have been possible to slide the range out some way and paint behind without disconnecting it, it is improbable that both the shortening of the kitchen cabinet and the painting could have been done without removal and replacement of the range.

6. The most probable explanation for the observed features is that the hose was detached from the range by unscrewing the upper clamp and pulling off the hose, so that the range could be moved out during the renovations. The range was then replaced but reinstallation of the hose was omitted, and it remained lying on the floor behind or alongside the range when the unit was handed back to the owner. At that time the LPG supply to the unit was off at the meter valve and there was no escape of vapour into the kitchen.

7. The question therefore arises as to why the range would have to be disconnected and moved at all, given that this is strenuously denied by both the designers and the contractors.

8. The design concept did not include any remodelling of the kitchen stove and sink area, as the intention was to locate the washing machine in the north-east corner of the kitchen outside the existing closet arrangement. This is shown in the concept plan reproduced below.

9. However it is not reflected in the Scope of Works under 'Architectural Works' which includes the phrase 'Kitchen-Washer/dryer cabinet'. From photographs taken after the renovation and the recreated layout derived from physical evidence, it was seen that a new wall section and doors were positioned west of the column forming the south-east corner of the kitchen. This would be necessary to make an enclosure deep enough for the washer/dryer. Thus it shortened the room and required the under-sink cabinet to be modified to allow the range to fit into the reduced space at the south-east corner of the kitchen.



PROPOSED FLOOR PLAN

Figure 43 – C+G Design Studio concept plan

(Not to scale – for illustration only)

Figure 44 – post-renovation kitchen layout,
photograph provided by Ms Cayton with annotations by Kroll

10. Comparison of the physical remains and dimensions of the under-sink cabinet with those fitted in other comparable units showed inescapably that it had been shortened at the east end. Whether this was done at the time of this renovation or previously could not be firmly established. However, there would have been no reason for this to occur when the range was in its former position abutting the corner column.

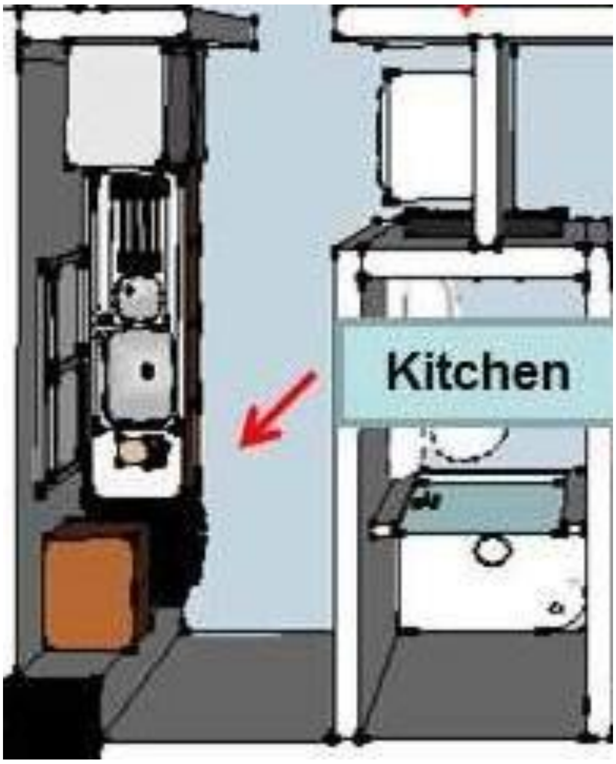


Figure 45 – pre-renovation layout
(Not to scale – for illustration only)

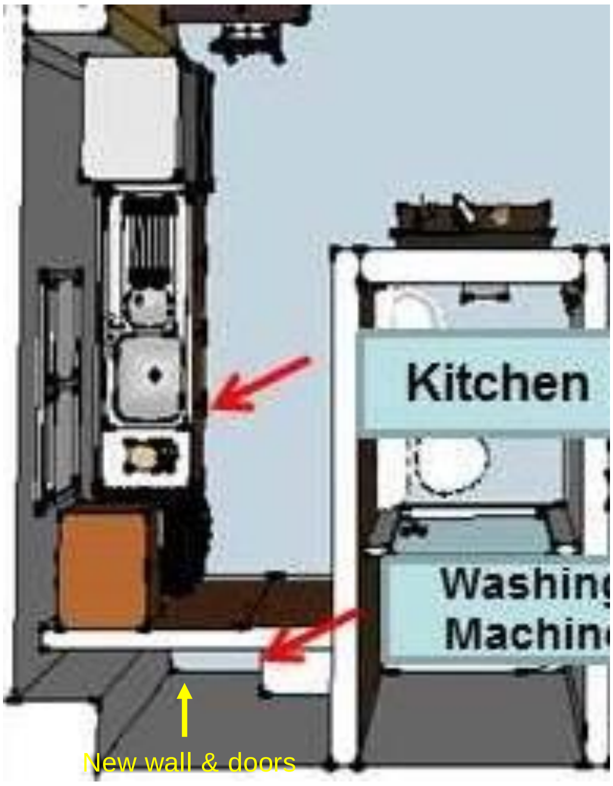


Figure 46 – post-renovation layout,
as deduced from evidence
(Not to scale – for illustration only)

11. The original stub-out and shut-off valve location shown in the as-built CAD plans was at the east end of the kitchen cabinet immediately alongside the range. The stub-out length measured using CAD was 2.53m, close to the length measured physically in the IATF office allowing for bends.

12. Shortening the under-sink cabinet and moving the range to the west by approximately 230mm would have the effect of positioning the valve behind the range, which could make it more difficult to place the range back against the wall. There was nothing to suggest that the stub-out pipe had been shortened but the presence of two elbow fittings may indicate that the valve had been moved or turned to accommodate the new location of the range.

13. In many countries, white tape is used only for water pipe connections while yellow PTFE tape with slightly different properties is used specifically on gas and LPG pipes. It has not yet been verified whether this applies to the Republic of Philippines. In the absence of a formal Gas Standard, tape colour is unlikely to be regulated.

14. It was noted that white thread tape was used on the gas fittings in this unit and throughout the building. This makes it impossible to distinguish visually between gas joints correctly installed by a certified fitter and those made by a plumber or DIY enthusiast using water joint tape.

15. The IATF initial report identified the painter Mr Cuizon as responsible for moving the range and failing to reconnect the hose, during his painting tasks. However, earlier disconnection during the kitchen remodelling stage was considered more probable by Kroll based on the above factors.

16. This was confimed by the later witness evidence quoted in the IATF report of 14 August 2013. It was established that the hose was disconnected by Mr Reynel Infante on 7 May and the range moved to the sala (p. 68). The hose was reportedly reconnected when the range was replaced on 17 May by Mr Cuizon and Mr Zamora. However the physical evidence clearly showed that it was not connected to the range at the time of the incident.

17. Irrespective of the reasons for the hose disconnection, LPG vapour would have flowed through it unhindered from the time the ball valve was turned on. Mr San Juan was in the unit from early afternoon, at which time the air conditioning and possibly other power supplies were off. He complained of feeling 'suffocated', which would be consistent with accumulating vapour in the unit displacing some of the oxygen. This would be most probable if his head was in the denser part of the vapour cloud, i.e. in a low sitting or lying position.

18. The lack of air conditioning would be likely to cause him to use the pedestal fan, which was seen to be on by Mr Falcasantos later in the evening. The air movements thus produced would mix the vapour and air more effectively and decrease the layering effect of the dense vapour. It is possible that he also opened external windows for ventilation due to the heat and suffocating feeling, which would explain the loss of a substantial amount of the escaped vapour from the unit.

19. Since Mr San Juan had arrived from the USA that morning, it would not be surprising if he wished to rest and/or sleep during the afternoon. A combination of natural tiredness and the effects of the vapour inhalation would explain the difficulty in waking him described by Mrs Ochoa and the security guards.

20. The position of Mr San Juan relative to the ignition source for the explosion can be determined from his injuries. The lack of blast, crush and penetrating debris effects indicates that he was close to the epicentre. This is supported by the whole-of-body burn distribution, with more severe patches probably associated with burning clothing adhesion to the skin.

21. The brief description Mr San Juan was able to give to Mrs Ochoa before hospitalisation indicates that he was at or close to the unit door at the time of ignition. Immediately beside the door were two electrical switches, one for the lights and the other a main power override switch. On laboratory testing, the latter was found to be in the OFF position.

Figure 47 – original location of switches beside door,
with photograph of positions as found after explosion

22. Only a few minutes previously, a light and a fan had been noticed operating in the unit. It is therefore probable that Mr San Juan had prepared himself to leave, approached the door and opened or started to open it while switching off the main power switch for the unit. The parting arc produced by a 220V AC circuit under load has sufficient energy to ignite an LPG vapour-air mixture anywhere within its flammability limits.

23. Support for the ignition source being the switch is given by the vector plots indicating the explosion epicentre within approximately 1m radius from the front door. This also corresponds with the burn injuries suffered by Mr San Juan standing and then falling within the same area. The only other viable ignition source located nearby was the switch for the decorative floor lamp between the front door and the sofa.

24. It has been presumed by all investigators that Mr San Juan was a non-smoker, based on the available information. If this is shown to be incorrect, then attempting to light a cigarette while leaving the unit would be a viable alternative ignition mechanism.

25. The relative humidity outdoors at the time of ignition was approximately 70% (Appendix B). In the absence of air conditioning for most of the day, and the possibility of open windows for at least some of the afternoon, the humidity inside the unit would be expected to be similar. Thus static electrical discharge between clothing, shoes, soft furnishings etc. can be eliminated as a potential ignition source.

26. The reason for Mr San Juan's mention of feeling 'electrocuted' is most probably a result of the still energised electrical panel being detached from the West bathroom wall and falling onto the tiled floor, which was simultaneously being drenched from the ruptured sprinkler pipes.

5. PART ONE CONCLUSION

1. The explosion was initiated within Unit 501B at approximately 19:59:31 local time, as recorded on the 2 Serendra CCTV system time stamp.

2. It did not result from the operation of a manufactured or improvised explosive device, or any other solid or liquid explosive material.

3. The explosion and resultant structural damage occurred when a mixture of LPG vapour and air within its flammability limits was ignited. This produced a rapidly expanding flame front which pressurised the surrounding air beyond the resistance of the surroundings.

4. The pressure was sufficient to displace the East wall panel into the adjacent roadway, where it struck a vehicle resulting in three of the fatalities.

5. The source of the LPG vapour was an open flexible hose in the kitchen, intended to supply the cooking range but disconnected at a previous time and not replaced. The disconnection was almost certainly connected with the renovation activities.

6. The ignition source was most probably the operation of the main switch to turn off the power, as Mr San Juan was leaving the unit.

7. Because Mr San Juan was at the epicentre he suffered no penetrating or crush injuries but was severely burnt, resulting in the fourth fatality.

Kroll Advisory Solutions℠

An Altegrity Company

1701-02 Central Plaza
18 Harbour Road
Wanchai, Hong Kong
T +852 2884 7788