22 Aug 2013

Serendra Explosion Incident

Final Report – Part Two

Contributory and Associated Factors

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1. EXECUTIVE SUMMARY

1. Mr San Juan had been given permission to occupy Unit 501B without an engineer's inspection following the renovation. An engineer's inspection based on an accurate as-built plan should have identified the disconnected hose before reinstatement of the gas supply.

2. The gas supply to Unit 501B was reinstated by a relative of the owner who was not authorised to do so. However there is evidence to suggest that the meter cabinet doors were habitually left unlocked, possibly for convenience when reading the meters. If this door had been locked, it would have more difficult for the supply to have been reinstated without authority.

3. Commercial grade LPG vapour should emit a strong and unpleasant odour which is provided by a chemical known as ethyl mercaptan added to it. No-one in or visiting the building was aware of any such odour prior to the explosion, despite a high flow rate of LPG vapour within and from the unit.

4. It is apparent that much of the ethyl mercaptan odoriser was lost at the vaporisation stage before the vapour was supplied to the Bonifacio Global City piped gas system. Thus the vapour escaping at Unit 501B and at other locations tested did not have the usual strong and unpleasant odour alerting occupants to a leak.

5. The gas sensors fitted in the condominium units were fitted with normal 220V AC power supply plugs and could therefore be disconnected by the occupants or persons working inside the units. The electrically-operated valves to which the sensors were connected remained open when de-energised. Thus it was possible for LPG vapour to escape without being detected by the sensor and/or closing off the valve.

6. In addition, physical evidence indicates that the gas sensor in Unit 501B was probably positioned behind a newly-installed partition, effectively isolating it from the potential and actual sources of escape in the kitchen.

7. Parts of the building construction did not meet the requirements of the National Fire Code and/or parent documents issued by NFPA in the USA. Specifically, a number of vertical ducts and chases were not fire-stopped between levels. Although no fire followed the explosion in this case, that result was fortuitous. Had a fire developed, it is likely that there would have been

spread from the 5th floor to other levels. The same ducts and chases provided a pathway for pressure wave travel between levels and into the roof.

8. External and internal wall fixings to the horizontal slabs were insufficient to resist the overpressure and this resulted directly in the projection of the east wall concrete slab onto the road way, causing three deaths. It is fortunate that neighbouring units were unoccupied at the time of the incident; otherwise there would most probably have been more deaths and serious injuries resulting from the structural response.

2. CONTRIBUTORY AND ASSOCIATED FACTORS

2.1 The Building Construction

1. The external and internal corridor wall construction method used infill panels of mesh and Spraycrete between the concrete beams and columns. It is understood that this part of the design is related to the wind shear protection required in the local climate. The panels were anchored to the beams by means of protruding steel mesh ends acting as pins, inserted into drilled holes in the beams.

2. It was noted that both the spacing and depth of the pin insertions was variable throughout Unit 501B. Since destructive examination would have been required to compare other units this was not undertaken at that time but could be done during any subsequent remediation or demolition.

3. Original internal walls were of lightweight rendered block construction around vertical steel rebars, which again protruded and acted as pins inserted into drillings in the slab. The spacing and depth of these was also variable, with some inserted as little as 7mm (0.28”).

4. It was also noted that there was no suitable sealant or other firestop material between the walls and ceiling slabs. This is a requirement under the Republic of Philippines National Fire Code 10.2.6.2 F1 and its parent document NFPA1.

5. We recommend that a competent structural engineer, knowledgeable with national and local building codes, review IATF data relative to construction of affected buildings to offer further advice on compliance.

6. The existence of open vertical ducts or chases from ground to roof level has already been mentioned in Part One. These were major routes for pressure wave travel through the building and therefore responsible for some of the more widespread damage. Had a significantly sized fire followed the explosion, then the presence of these openings would have permitted rapid fire spread to involve the upper levels ad roof, which could have had serious consequences for the evacuation procedure. Again, firestopping of such ducts is required under the National Fire Code and NFPA.

7. Elevator shafts have to be open to all levels by their nature and special provision is made for them in the Fire Codes. Better protection against overpressure effects can be provided by

changes to elevator lobby design, such as baffle walls and vent panels. However it is accepted that internal explosion protection is rarely a priority in residential building design.

2.2 The LPG Supply and Safety Features

1. The escape of LPG vapour into Unit 501B and subsequent leakage into the corridor remained undetected for approximately 13 hours of normal building occupancy. This indicates that (a) the vapour itself did not activate the sensor in the unit or the one at the base of the riser in 101B meter cupboard, and (b) the characteristic strong unpleasant odour of the added odorant ethyl mercaptan was not detected by anyone entering or going to the unit or passing through the common areas during the day.

2. The possible reasons for this have been considered. In the case of the detector within the unit, there are several possibilities. Firstly, the detectors are designed to be plugged in to a normal socket outlet. This raises the possibility that they may be left unplugged or switched off at the wall, in which case no amount of LPG vapour escape will operate detector and hence the shut-off valve. Because the valve is a fail-open design, lack of input from the detector does not result in closure of the valve.

3. Examination of a unit with a mirror-image layout (303B) indicated that the socket outlet closest to the range and thus normally used for the detector was on the end wall of the kitchen, forming part of a double outlet also supplying the range. The detector was on the side wall directly above the shut-off valve, approximately 0.8m above floor level. This would allow a substantial vapour accumulation at low level before the 20% LEL threshold was reached at the detector height. In this unit, the detector was not plugged in when examined.

4. However later inspection of the as-built CAD plans for 501B showed the socket outlet for the range on the west face of the south-east column, prior to renovation. No power outlet is shown in the original closet area at the east end of the kitchen.

Figure 48 – gas detector, shut-off valve and power supply in Unit 303B
Note double socket outlet on end wall, only range plugged in

5. The changes to the kitchen in 501B as a result of the remodelling would probably have concealed both this outlet and the sensor location behind the doors and wall shown in Figure 44 of Part One. In addition, at least one power outlet would have been needed at the end wall for the relocated washer/dryer. There is no record of additional power outlets having been installed in the kitchen, thus it is reasonable to presume that the range supply was either left disconnected (which could explain the hotplate control position) or had been passed through a hole in the new partition alongside the doors in Figure 44 to reach the outlet on the end wall.

6. The gas leak detector from Unit 501B was recovered and examined. Its plug prongs were straight, indicating that it was probably not plugged in when propelled from the building. Further, the examination of the electrical panel showed that the circuit supplying the adjacent outlet was OFF.

7. In either situation, it would strongly suggest that the gas detector was (a) probably not energised and (b) separated from the range by a partition, thus greatly reducing its potential effectiveness in the event of a domestic accident such as leaving a hob burner on but unlit.

8. If a fail-safe (normal-off) shut off valve was fitted, then non-operation of the detector for any reason would result in a closure of the supply. The valve in use in this and reportedly other units was a normal-on type, which fails in the open position.

9. Because LPG vapour is denser than air and there is witness information that the meter cupboard door was open, some of the vapour which escaped into the corridor could have descended the riser duct to ground floor level. There was a sensor there which did not operate.

10. The test results for this show that is was found switched OFF and remained inoperative when supplied with power and switched on. Although it could have been disrupted by the explosion, its location makes this improbable. It is more likely that it was non-functional prior to the incident. The absence of gas detectors within individual meter cabinets or dropper ducts would allow gas to enter them from the corridor without activating any alarms.

11. The other method of detecting a vapour escape is by odour. Because LPG is naturally odourless, a distinctive and unpleasant odorant is added by the manufacturer or supplier; in this case, Shell supplied BGC with liquid LPG to which was added one of the common industry odorants, ethyl mercaptan. This is a sulphur compound variously described as smelling like garlic, bad eggs, foul drains or similar unpleasant odours. Most human beings are sensitive to it at low concentrations, although sensitivity may decrease with age. Appendix G contains relevant material concerning ethyl mercaptan and gas odorants in general.

12. No-one in 2 Serendra reported such an odour on the day of the incident. Specifically, it was not detected by Mrs Ochoa and the two security guards at the doorway to Unit 501B immediately prior to the explosion. At that time the LPG vapour concentration in the unit would have been around 4-5% and the odour should have been overpowering both inside and directly outside. It would certainly be expected to have masked the odour of water-based paint, which was apparent to Mrs Ochoa and Mr Falcasantos.

13. Ms Kangleon and Mr Bernas reported an odour which they recognised as LPG after the explosion, but only when they were close to compromised meters and supply pipes. Both described the odour there as weak, when it would be expected to be extremely strong in those locations.

14. Ad-hoc olfactory testing after the explosion by BFP members FSInsp Abad and SFO1 Polo at the Brasilia restaurant supplied by the same underground system revealed a very weak odour at the gas range burners, which could not be noticed more than a few centimetres away.

15. Testing using a PID instrument indicated an ethyl mercaptan concentration in the LPG vapour of approximately 1.1×10^{-8} ppm. The accepted minimum concentration for odour awareness is 1.5×10^{-4} ppm. Thus the measured ethyl mercaptan concentration was less than one ten-thousandth of that needed for the escape to be readily detectable by odour.

16. Olfactory testing was also carried out by Kroll at BGC on 16 July 2013, when it was noticed that the odour of vapour vented directly from the underground liquid storage tanks was very strong, as expected. However, opening a valve immediately downstream of the vaporisers resulted in a weak odour which was undetectable more than a few centimetres away.

17. This supported the previous findings of the BFP personnel at the Brasilia restaurant, and indicated that most or all of the odorant loss was occurring at the vaporisation stage rather than in the underground polyethylene supply pipes or the black iron pipes installed in the buildings.

18. Appendix G includes published material referring to this phenomenon, as well as loss of odorant in new iron and steel pipes and containers. In short, loss of odorant during vaporisation is a recognised problem in the LPG supply industry and a range of methods has been developed to compensate for it.

19. The building at 2 Serendra was completed in 2008 and the LPG black iron pipes had been in use for approximately five years prior to the incident. Their contribution to odorant loss is therefore considered negligible. The underground MDPE pipes are known to have very low affinity for odorant molecules and can therefore be disregarded in this context.

20. NFPA 58:2008 Liquefied Petroleum Gas Code Section 4.2 (current at the time of installation) reads as follows:

> **4.2 LP-Gas Odorization.**
>
> **4.2.1*** All LP-Gases shall be odorized prior to delivery to a bulk plant by the addition of a warning agent of such character that the gases are detectable, by a distinct odor, to a concentration in air of not over one-fifth the lower limit of flammability.
>
> **4.2.2** Odorization shall not be required if it is harmful in the use or further processing of the LP-Gas or if such odorization will serve no useful purpose as a warning agent in such further use or processing.
>
> **4.2.3*** If odorization is required, the presence of the odorant shall be determined by sniff-testing or other means, and the results shall be documented as follows:
>
> (1) When LP-Gas is delivered to a bulk plant
> (2) When shipments of LP-Gas bypass the bulk plant

21. When inspected, the BGC plant had no system or equipment to determine the odorant concentration in the LPG vapour at the tanks or entering the distribution system. The only method available to check the odorant concentration was an uncalibrated 'sniff test'. The operating engineers expressed the view that they were not familiar with odorant chemistry or usage, and relied wholly upon the correct dosage in the incoming liquid fuel from the LPG supplier.

2.3 The Renovations to Unit 501B

1. There appears to be some variance between the design concept for the renovation, the scope of works, the daily work records and the final version. However in the absence of as-built plans and a subsequent engineer's inspection report, the details of the completed work are restricted to what can be reconstructed from the physical evidence and Ms Cayton's photographs.

2. It is clear that a substantial amount of electrical work was carried out, including the relocation of the circuit breaker panel to the west wall of the bathroom and the provision of socket outlets for the newly separated bedrooms. While there is no record of electrical work being carried out in the kitchen, this possibility cannot be eliminated from the available information.

3. It is understood from witness accounts that the electrical work was carried out and/or supervised by Mr Danilo Gruta, who was described as not a licensed electrician. The 2 Serendra *'Design and Construction Guidelines'* specify that alterations must be done by accredited contractors. It is unlikely that Mr Danilo Gruta could have been accredited if he was not licensed.

4. While changes to the electrical supply were not directly responsible for the explosion, it is possible that disconnection or non-operation of the gas detector in Unit 501B was associated with those activities.

5. In their initial statements the foreman Mr Manuel Gruta stated that Mr Cuizon, the painter, moved the range. Mr Cuizon admitted to having moved the range slightly to paint the wall behind. He did not admit removing or handling the flexible hose. The kitchen was fairly small with restricted room for movement and it is considered unlikely that moving the range out (northward) just a small amount would be adequate to access the whole of the wall behind. There is strong physical evidence that the hose was horizontal and therefore probably lying on the floor during the painting.

6. Thus if Mr Cuizon did not remove the hose, it must have been done previously. The records of carpentry work carried out include a bed base, cabinets etc. associated with the bedrooms and unspecified work in the kitchen noted on the Scope of Works as 'Kitchen-Washer/dryer cabinet', despite Mr Manuel Gruta's statement to IATF that the scope of work did not include work in the kitchen.

7. As previously noted, the construction of a cabinet deep enough to take the washer/dryer and clearly shown in the post-renovation photograph at Figure 44 would have necessitated movement of the range to the West. If this was abutted to the end of the existing under-sink cabinet, shown in the pre-renovation as-built CAD plans, then the cabinet would need to be shortened to accommodate this movement.

8. There is strong physical evidence that this was done and it is difficult to see how it could be achieved without removing the range, or at least moving it some distance, and disconnecting the gas supply. Two of the contractors, Mr Rodel Gimena and the electrician Mr Danila Gruta, told CIDG that they had seen the range 'at the corner of the sink'. According to the daily attendance records, both were present on days before Mr Cuizon began to paint the kitchen.

9. Comparison of the daily attendance lists with the statements provided indicated that fourteen additional personnel were present at various stages of the renovation but were not interviewed in depth, or at all, at the time of the Kroll site investigation. They are listed at Appendix J.

10. Subsequent interviews described in the IATF final report confirmed that the gas range was removed and replaced to facilitate the renovations.

2.4 Rules and Procedures Relating to 2 Serendra

1. Two documents were provided in English entitled *'House Rule and Regulations'* and *'Design and Construction Guidelines'*. There was apparent confusion in language and intent, with the Rules containing some non-mandatory statements and the Guidelines containing mandatory language.

2. Clause 11.7 of the Rules states: *'Residents are not allowed to use LPG (liquefied petroleum gas) tanks since we have our centralized LPG system that was provided with a meter.* ***It is advised*** *that residents also install their own automatic shut-off mechanism as additional for fire safety precaution'* (our emphasis).

3. However Mr Opiso of Direct Power Services Inc. stated that for LPG to be supplied to a unit, a sequence of steps had to be followed:
   - Owner applies for activation of LPG supply
   - Signs LPG service agreement
   - Pay activation fee and first bill deposit
   - Unit owner hires a contractor to install an LPG safety device and inform management
   - Management schedules activation
   - Activation team goes to the apartment to conduct pre-activation safety testing, conduct leak test and safety device test
   - Open the valve in the outside cabinet
   - Activate service
   - Unit owner signs activation forms

4. Mr Opiso stated that the *'Serendra policy of sensor and shut-off valve in each unit is mandatory'* and the *'LPG supply does not get activated without safety devices'*. Therefore the supply and professional fitting of a shut-off device was not advisory. Further, the recommended model of shut-off device was supplied by the Serendra Condominium

administration. This was an Electromotion Ball Valve but the available photographs do not clearly depict the make and model details. The detector was a 'Home Alert' brand. It has not been possible to identify the supplier or other characteristics of this detector without further information.

5. Mr Opiso also stated that there was a standard procedure for deactivation of the LPG supply to a Unit as follows:

- Unit owner provides a form and logs it with the lobby guard
- UMG checks with the unit owner before coming to deactivate
- Deactivation team goes to the LPG cabinet to record the final meter reading in the presence of the unit owner, close the supply valve, and tag the valve
- Complete deactivation forms and write meter reading
- Owner signs and gets a copy
- UMG gets a copy

6. Reactivation was described as a reverse of the above process, with a UMG operator un-tagging and opening the valve. Mr Opiso also stated that the unit owner should not have access to the meter cupboard which should be kept locked.

7. This description contrasts with Mrs Mendez's statement that *'it is the "SOP" for the unit owners to open the gas and valves leading to the unit when entering the same, and to close the same valves when no one was occupying the said unit'*.

8. Thus there seems to be confusion between the residents' (or caretaker's) perceptions and those of the responsible body concerning the correct policy and procedures regarding LPG use.

9. In respect of the 'Guidelines', Section 3.2 Normal Power System, clause 3.2.4 states *'all alterations must be done by the accredited contractors*'. No records have been seen which indicate that RM Ladrito Constructions was an approved contractor for the purpose of this document.

10. Clause 3.4.2.4 reads *'Convenience outlets installed for hazardous location shall be explosion proof type'*. There is no accompanying definition or example of a hazardous location, and I would not expect to find such a location within internationally-accepted definitions inside a residential unit. The only possible exception would be the outlet adjacent to the gas supply, which was a normal domestic fitting.

11. Section 5.3 LPG Installation contains the following mandatory statement at 5.3.1: *'The unit owner **shall** provide the cooking equipment, industrial type flexible hose and necessary connections for each residential unit while the shut off valve and gas meter at the main tapping point has already been provided'* (our emphasis). This contrast with the house rules clause 11.7 at 200 above.

12. At 5.3.4.1, the owner is instructed to *'Provide gas leak sensor and automatic safety device/s between the regulator and the burner which will stop the flow of gas should a leak develop'*. This instruction appears in the Design and Construction Guidelines rather than the House Rules and Regulations.

13. There is anecdotal evidence in the statements to indicate that some residents had experienced false alarms from their unit gas detectors and had been advised to disconnect them. Ms Rosita Bonifacio-Tolentino told CIDG that during one year her sensor sounded twice but no leak was found and it was replaced by the supplier. Ms Kangleon stated that *'several tenants had an option of turning off their LPG sensors, in coordination with management'*.

3. PART TWO CONCLUSION

1. In common with many major incidents, the explosion occurred because of a coincidence of factors. Individually, each of them may have appeared relatively harmless but in combination they led to the series of events described in Part One of this report.

2. The explosion incident at Unit 501B resulted directly from a combination of circumstances including, but not necessarily limited to, the following:

   - Interference with the flexible hose supplying the gas range by one or more unauthorised persons, during renovation work which went beyond the approved Scope of Works.
   - Occupancy resumption after renovation without an engineer's inspection and certification.
   - Reinstatement of the gas supply to the unit by an unauthorised person
   - Lack of security of Unit 501B meter cupboard and failure to tag off the closed valve.
   - The presence of a shut-off valve which did not fail-safe when de-energised.
   - The weakness of the odorant in the piped LPG vapour supply, most probably resulting from losses at the vaporisation stage.

3. In addition to the direct factors, the situation was exacerbated by the following:

   - Lack of clarity and consistency in the 2 Serendra Condominium documents, policies and practices.
   - Lack of adequate supervision and checking of renovation activities.
   - Building construction factors which increased the extent and severity of the overpressure effects.
   - Lack of awareness among BFC engineers about odorant processes in LPG.
   - Lack of warning from LPG supplier (Shell or successor) to BGC about the potential decrease in ethyl mercaptan concentration after vaporisation.

4. Although gas and vapour explosions are relatively uncommon events in residential and light commercial buildings, experience has shown that observance of good practice and application of standards, codes and regulations would reduce the numbers much further. Since almost all of the circumstances involved in such incidents involve human error, limiting the amount of human interaction while increasing the use of automated systems is a desirable objective. This concept will be explored further in Part Three of this report.

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