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What Happened at Jilin Baoyuanfeng on June 3, 2013

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This report is in two parts – the first addressed to design professionals; the second to the public at large

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1.0 Preface

My report of the event discussed in the following pages is divided into two parts. The first, in this section, is analytical, reconstructing the event and its antecedents, for possible use by design professionals, in particular to those concerned with poultry processing. The second part, to be uploaded shortly, makes general suggestions on how safety enforcement officials can implement some simple rules to make workplaces and public places safer.

2.0 Déjà Vu

On 3 September, 1991, in the North Carolina town of Hamlet, USA, a fire in a poultry further processing plant owned by Imperial Foods killed 25 workers.

The story is detailed, among others, in two videos and two text reports on the internet[1] referenced here. In the light of these, the Jilin event evoked in me a deep sense of déjà vu. Workers at Jilin Baoyuanfeng poultry processing plant at Mishazi, Jilin Province, Manchuria, (JBPPP) probably experienced a sense of despair similar to the Hamlet workers on the morning of June 3, 2013. Locked doors, a maze of large rooms separated by moveable walls, equipment laid out in a series of zigzag workflow lines, boarded windows to prevent theft of chicken, insufficient safety inspections or compliance, narrow corridors, poorly marked or blocked emergency exits, toxic thick black smoke from the combustion of thermal insulation – they were all common to both tragedies!

Figures 1, 2. Imperial Foods Plant at Hamlet before the fire; Drop ceiling is barely over 3 metres high. *Source: World History Project, video- ibid*

But between these events there are differences, too. The Hamlet plant was nearly a century old, having served earlier for the production of ice cream, before Imperial Foods converted it 11 years earlier for its final role. The total area of the plant was 2790 sq metres, was single storied and there were only 90 workers inside the building at the time of the fire. Designers of the Hamlet plant had not had prior experience of poultry processing plant fires and so they had not anticipated or prepared for it. Their impression was that such plants did not contain much in-flammable stuff except for some packing materials. But a fire did take place, and it was traced to a failed hydraulic hose of the oil heating system in a Stein fryer. Unknown to them, partition walls (possibly sandwich panels) were also combustible.

JBPPP, on the other hand, was built as a green-field project in 2009. Knowledge of poultry processing plant fires was already available to designers, but was ignored. JBPPP had 395 workers trapped in the fire, which occurred in a modern steel building having a total of nearly **17,000 sq metres floor area - 1.7 hectares, or six times as large as Hamlet**, making rapid escape many times more difficult and time-consuming than the Hamlet fire.

A month before Hamlet, a Tyson plant performing identical functions with twice Hamlet's capacity at Arkansas, also coincidentally had a hydraulic system failure in the oil heating system of its Stein fryer. There were no fatalities, but the similarities were uncanny. The US Fire Administrations' report[2] following the Hamlet disaster compares the fire safety paradigms at both plants and offers constructive instructions for designers and consultants. It includes mention of fire prevention SOP's put in place by Tyson. So although since 1991 there have been many fires in poultry processing facilities worldwide, they have had minimum fatalities. These suggestions have been discussed in my second report on the subject

Poultry processing, specifically, is rapidly becoming mechanized and institutionalized in the third world. This recent event should become a wake-up call for all such developmental efforts. We also need to learn why lessons learnt in USA, so readily available on the internet, should fail to benefit the entire global community.

Following fires in sandwich panel buildings in the UK, and elsewhere, the Building Research Establishment in the UK and the Association of British Insurers developed the Loss Prevention Standards LPPS 1181, writes Professor James Lygate, Principal Investigator at IFIC Forensics[3]. All this has serious implications for not only designers and consultants but also leading suppliers of systems and equipment for the processing industry who claim to be at the cutting edge of technology.

Part two of this report covers these aspects for general safe construction not only in new poultry processing facilities being created in the third world, but the whole gamut of industrial and public spaces which may be prone to fire-related fatalities. It also draws a clear distinction between building codes and standards and objectives aimed at loss prevention. The latter relate to safety of workers and rescue personnel, but make no claims on reduction of possible financial consequences and insurance.

3.0 Dawn of June 3 at Mishazi in Jilin Province, Manchuria

Contrary to news reports, although the JBPPP facility (coordinates 44.136184,125.487696) may be administratively under Dehui, it is physically situated very close to the city of Changchun, North of the Changha Road (102 National Road) connecting Changchun-Mishazi-Dehui, just beyond the hamlet of Mishazi, about 100 kilometres North-east of Changchun and a short distance from a toll station. Mention of Dehui in almost all news stories may have been triggered by the initial report that JBPPP was one of the important processors in the Dehui area where the leading processor Jilin Deda was located.

3.1 The Facility

JBPPP is a new green-field processing plant set up in 2009, designed to process 12,000 birds per hour probably on 2 shift basis[4], to account for some 67,000 tonnes (2010 official data on website) of processed chicken per year, and employing 1200 workers (although only 411 of them had signed formal work contracts[5]). The company also owned chicken feed plants. Pictures published in the news media reveal details of extensive manual and semi-automatic secondary processing, i.e. production of bone-less and bone-in portions.

As of the end of 2010, it had sales of $38 million. An April 3013 job advertisement online posting, says the company had grown to $58.7 million sales in 2011 and was, at that time, hiring 200 additional workers. In recent years China has had to progressively shut down its "wet market" poultry retail system due to the spread of the AI virus – more recently the H7N9 strain – putting her poultry processing infrastructure under strain. So it is conceivable that this plant's unofficial capacity may be higher than the official figure. More on this subject in the next section.

Only one picture shows packaged RTE food produced at this facility. This amounts to inconclusive evidence about the facility producing RTE products.

Figures 3,4. The upper picture shows a probable packing material receipt gate. The bottom picture, taken from across the highway near the main gate area, shows the admin building on the left.

3.2 The Incident

At 0606 hrs on June 3, 2013, as the plant was undergoing a shift change, an electric short circuit started a fire leading to three large explosions. There were some 395 workers at site. 121 were killed, 77 hospitalized, with most of them treated for smoke-induced injuries. News reports said that an electric fire in a workers' rest area ignited a concentration of leaked ammonia.

The fireball raced through the processing hall (cut-up, de-boning and packing hall) rapidly (3 minutes, by some accounts), leaving very little time for workers to flee. Simultaneously with the explosion the power went out, leaving workers to panic and trample over each other as they sought exits.

The accident was neither notified by an audible alarm, nor were the passageways lit up by any kind of emergency lighting systems. Air extraction systems or negative air flow systems automatically operable in the event of an accidental ammonia release, if they existed, failed and smoke rapidly concentrated within the building. Fire extinguishers were probably installed, but were not used because of panic, lack of emergency drills and training, and failure of lights. To add to the mayhem, the complicated layout, inadequate and inconveniently placed exits, and possibly locked exits resulted in lots of deaths. Nor were lessons leant - according to one worker there was an earlier fire three years ago, also involving ammonia, ignited by a cigarette.

Significantly, this fire occurred a week after Smithfield Foods Inc, America's largest pork processor, announced an acquisition deal by the Chinese pork processor, Shuanghui International Holdings Ltd, as a solution to recent lackluster performance of the pork market in USA. Recent news of deliberations over this deal indicate that the main objections raised against this acquisition were not the poor Chinese record on plant safety and lack of compliance with existing standards, but strategic concerns about Chinese control of pork meat supplies within USA.

3.3 What It Means to The Design Professional

Besides management deficiencies and use of their *Guanxi* or cronyism with local safety authorities to disregard safety rules, what concerns us here are the design aspects of the facility. I believe, that as professionals engaged in designing poultry processing facilities, and as technology leaders in the art of poultry processing, we can make some observations from these circumstances which may help us make better and safer facilities. What also concerns us here is a better understanding of local cultural habits and norms that can render even the best and safest machine design futile.

I treat this as an opportunity for an industrial designer, appropriate especially for India and a number of growing economies where lack of standards, cronyism with the authorities leading to compromise of worker welfare and safety, by-passing existing safety features on machinery and plain bad designing are the norm, and will likely stay so for a long time.

4.0 Stated Causes of the Incident

To make my analysis, I have carefully examined eight independent news stories (there are many others, but they essentially repeat earlier stories) in the public domain. I then made a frequency distribution study of stated causes of the disaster or those leading to the disaster. Based on the emerging evidence I then scrutinized over 70 photographs downloaded from Google's graphic store to reconstruct the event and draw inferences.

Table 1 – Reported Causes of the June 3 Disaster

Possible causes, design, behavioural & operational shortcomings, culled from eight[6] independent published accounts

1	**How The Fire Originated**	**Inference**
1.1	Fire may have originated in a locker room	-
1.2	Fire started at 6 AM following an explosion. Smoke quickly filled the air	-
1.3	Fire electrically sparked into leaking ammonia	Ammonia designing
1.4	Ammonia gas leak	Ammonia designing
1.5	Three large explosions were followed by a fire	Ammonia designing
2	**Local Community Involvement and Response**	
2.1	Collateral injuries in adjacent township	Facilities nearby
2.2	120 died, approx 100 escaped, some 60 of whom received injuries. 3000 residents of nearby hamlet were evacuated following leakage of ammonia	Facilities nearby
2.3	500 firefighters were pressed into service, many doctors and nurses	Facilities nearby
2.4	Building was charred – the fire took 6 hours and 500 firefighters to douse	Facilities nearby
3	**Relevant Plant Construction Features**	
3.1	Steel frame, mainly single storey building, with many adjoining huts, was made of prefabricated concrete walls and had a corrugated iron roof with insulating sandwich panel false ceiling and wall insulations and plenty of partitioned internal workrooms	Inconclusive *per se*, construction details analyzed in this report
3.2	Plant built with combustible materials	Sandwich panels
3.3	No one had time to use fire extinguishers	Analyzed in this report
3.3	Fire engulfed the building in 3 minutes	Fireballs from seat of fire
3.4	Inhalation of toxic gas	Analyzed in this report
3.5	Struggled *through smoke and flames* to reach exit	Analyzed in this report

4	**Layout Details**	
4.1	Cluttered layout	Analyzed in this report
4.2	Had too few escape routes	Analyzed in this report
4.3	Narrow and cramped exit routes	Analyzed in this report
4.4	People trampled each other in their bid to exit through the single open door	Analyzed in this report
4.5	Employs 1200 workers, but only 350 were believed to be at the site at the time of the fire	Analyzed in this report
4.6	In a similar accident, workers dormitory, factory and product warehouse were in the same building	Analyzed in this report
4.7	200 tonnes of chicken per day. Or 10,000 to 12000 birds slaughtered per hour	Layout, capacity reviewed
4.8	Tight layout inside the plant	Analyzed in this report
4.9	High number of employees – high manpower density	Analyzed in this report
4.10	Some doors were too far to reach	Analyzed in this report
4.11	Complicated interior structure of the building and its narrow corridors, narrow exits caused not only panic to exit, but also hampered rescue efforts	Analyzed in this report
4.12	Stampede ensued	Analyzed in this report
5	**Absent Safety Features**	
5.1	Panic evacuation follows someone shouting “Run away!”, not an alarm siren as one would expect.	Design
5.2	Not equipped with appropriate fire safety and emergency measures	Management
5.3	Lacked extinguishers	Management
5.4	Lacks basic emergency equipment	Design, Management
5.5	No emergency lighting	Design
5.6	Plant went dark and smoke billowed around	Design - cable positioning
5.7	The lights went out .. causing panic and stampede	Design - cable positioning
5.8	Power was cut off after the fire started	Design - cable positioning
5.9	Lax safety norm enforcement	Management
5.10	Poor worker training	Management
5.11	No evacuation drill or training to workers	Management
5.12	Pre-existing safety features on machines frequently bypassed in the interest of speed and productivity	Compromise and greed
6	**Exits Locked or Blocked**	
6.1	Most escape routes were locked	Management, Design
6.2	Bolted doors	Management
6.3	Some exits were locked from outside as well	Management
6.4	All but one door were locked	Management
6.5	Single unlocked exit from portioning hall	Management, Design
6.6	Emergency exit at workstation could not be opened	Design
6.7	Only a side door was open, the other exits being locked	Management
6.8	Doors were locked	Management
7	**Safety Administration and Laws**	
7.1	Local authorities praised the plant for its economic role in the community. It was called among top 100 agricultural processing companies	Cronyism
7.2	Unnamed government authorities share fault	Cronyism
7.3	Too much local *guanxi*	Cronyism
7.4	China has a raft of *vague* laws on workplace safety	Cronyism
7.5	Corruption and cronyism with local bureaucrats	Cronyism
7.6	Economic concerns override safety	Compromise and greed
7.7	Safety replaced by production and energy efficiency	Compromise and greed
8	**Special Points**	
8.1	Massive economic protectionism, which has stymied the province's economic growth	Special Point
8.2	Chinese workers cannot effectively unionize	Special Point
8.3	The accident comes just a week after America’s largest pork processor Smithfield Foods Inc announced a deal to be acquired by the Chinese pork processor Shuanghui International Holdings Ltd	Special point

In the rest of this article, we will assume that although these observations may or may not be completely true, they do reflect the general perception and where they have been based on reportage of interviews and on-the-spot physical observations, some or most, of the above causes may be taken as true for the purpose of my analysis.

5.0 Design and Construction

Refer to Figure 5. The hut in the forefront (West end) probably served as one of the dispatch sheds. Under the first window to the right of its solitary door, one can see a wheeled trolley. Figures 5 and 17 show this and another wheeled trolley, which were probably used to ship out finished goods cartons into dispatch trucks. That the floor level of this dispatch bay is at road height probably mandated loading with the help of a fork lift. Not visible in this picture, there is another dispatch door – on the North side.

5.1 General Layout Drawing

With the help of Google Maps, plausibility checks and a careful examination of over 70 photographs, it is possible to create an Autocad drawing of the plant.

Such a drawing may still be as much as 10-15% in error on actual dimensions, however, it does permit review of the circumstances leading to the incident and evaluation of my analysis by other design professionals. Such a drawing has been made by me. It appears as Figure 23. It shows the entire 10 hectare factory plot. I would welcome alternative interpretations and views from readers of this article.

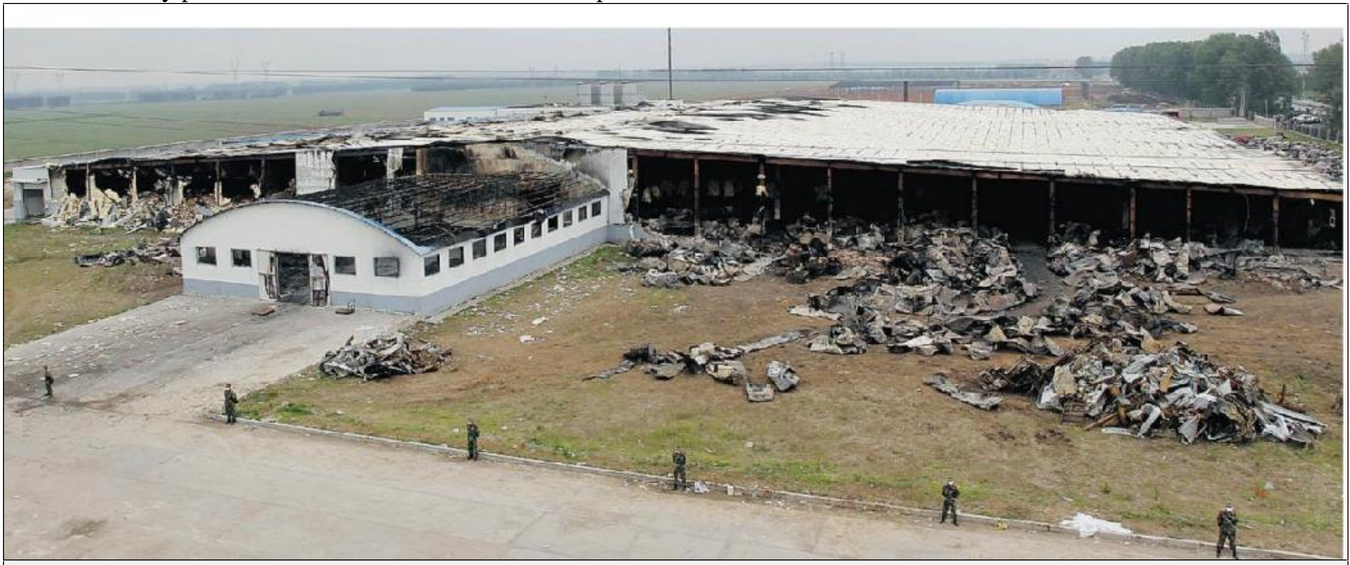


Figure 5 - Aerial View of the plant after the fire had been controlled and guards were posted on its perimeter. This picture shows that the North half of the building was completely gutted, though the South half, except for the central ridge, remained substantially intact. Except for the entrance hut in the centre, there was only one other door (on the right) which has been obscured in this picture as a result of rescue activities, and the entire front of the building was closed to traffic – the lawn giving ample testimony to this by bearing no signs of footpaths. (Light traffic was however possible over the plinth protection skirting the building). In the back, representing the East end, are the canteen - a multi-storey building, the boiler and chimney and the blue dome like structure is one of two Quonset huts[7] in the complex.

Towards the West end, behind the three multi-storey administrative buildings and the parking lots, are three huts- probably a hostel for essential staff. Near the main gate lies a time-keeper or security guard hut, and behind it, within a green belt, is a long blue motorcycle shed. The South end of the main process building also shows four pathways for workers' entry into the main plant.

Figure 6. This view, taken from the main gate shows the buntings, motorcycle shed, boiler chimney and canteen building on the far East end

The East end houses a mix of sheds, RCC buildings and some structures which defy analysis. The biggest shed appears to be the live bird unloading porch – the road passes right through it – which is how it should be. The clear existence of an effluent treatment area at the extreme East end of the plot precludes any doubt that this indeed is the live bird arrival end. There is even a gap in the East side fence for dumping effluent sludge into nearby farm land and there is evidence of such dumping in Figure 24.

This being the case, the East end would normally not contain any delivery gates, nor purpose-constructed workers' exits, except possibly a canteen. But a canteen for so many workers would almost certainly be a multi-storey structure connected to the main process area with a covered passageway which could also be useful as an escape destinations, provided the interconnecting doors were left open. The ground floor of this canteen building might serve as the central refrigeration plant. A likely candidate is the building marked Bldg 03 in Figure 23. The East end also houses the boiler – a chimney appears there in several photos, as in Figure 5.

5.2 Slope of Terrain and Number of Floors

The land slopes from the West towards the East and North-East. While there is no plinth separation on the West side – the road being at the same height as the plant floor - the East end is substantially higher and has sets of steps leading in (Figures 7, 8, 11 and 12). Since bird arrival end should have a plinth of approximately 1200mm above the road, one can conclude that a natural slope has been used advantageously in the design.

The main process building has a plinth of approximately 17000 square metres (140m x 120m). It has a peak height of 14-15 metres (Figure 21) and an average height at the North and South ends, of between 7 and 8 metres. Assuming that the inside floor was level throughout, the building houses some 185,000 cubic metres of workspace. Above this general floor space would be a false (drop) ceiling at approximately 6 metres, which would create a plenum to carry utility pipelines and cables. Many pictures show the delaminated false ceiling panels still dangling precariously at approximately this height.

In deciding whether this plant had a uniformly level floor and therefore one single work floor with a false (drop) ceiling at approximately 6 metres, we have to contend with the rather large slope of the land at the North-East end as evident from Figures 7, 8, 11 and 12. If this is true, then above the ground floor at these ends would be an additional floor which could serve as a service area or workers' rest rooms. Some credence is granted this hypothesis in Figure 20 which shows what appears to be a pair of insulated vessels in an area having guy wires – the existence of guy wires suggesting that this space was not a regular workplace but possibly a service facility, off worker limits.

Further, I believe, looking at standard layouts of similar capacity plants (Figure 22), that the given floor area was more or less comparable for primary processing at 12,000 birds per hour. But the fact that the natural slope of the land could have allowed division of the building into two stories at the East and North East ends appears to lend credence to the repeated comment about the complexity of this plant's interior. If the floor space was augmented by making part of the shed double storied, then the production capacity could very conceivably be much larger than officially stated.

The plant probably ran round the clock, with two primary processing shifts (slaughter, up to carcass chilling) of 8-9 hours each and three secondary processing (cut-up, de-boning and packing). This would make 5 work shifts in all, or considering that the primary shift needs less manpower, four roughly equivalent manpower shifts of 300 persons each. So at any time the maximum number inside the plant would be two shift eqivalents – i.e. 600 persons. The plant would run round the clock, with possible overlaps between production shifts, and a couple of hours for cleaning between them probably twice a day

Figures 9, 10. Estimating shift capacity and probable number of workers present in the plant at the time of the fire. Top picture shows a J Shackle Stork line or its clone with the remains of a belt conveyor. Bottom picture shows trimming tables of typical height 800mm, arranged end to end. False (drop) ceiling in the bottom picture is at approximately 5-6 metres above FFL.

5.3 Work Flow

Typically the East end of the building would be mostly devoted to primary processing (i.e. arrival, killing, de-feathering, evisceration, chilling and maturation. Live birds arrive at the East end, and the process continues in a linear pattern till the work flow reaches the West end or close to that end of the building. Work flow would then takes a U bend, double back-and-forth in a zigzag fashion incorporating the portioning, de-boning and packing areas till it reached the central ridge of the building.

The next line of workspaces running essentially under the central ridge of the building and effectively transporting the product from South to North, would consist of portioning, de-boning, trimming of portions and packing them.

North of the this would be the product stores. Since the news stories speak of fresh chilled supplies being the principal produce of this facility, the stores would be typically at -1 to +4 degrees C. The entire workspace after maturation would be held at +12 degrees C.

North of the central ridge the shed has two longitudinally running sets of roof monitors, possibly provided with glazing and vents (Figures 22 and 23). That they do have vents is evident from the large amount of thick black smoke apparently issuing out of these vents in Figure 3 and 4. Going to the East of this part of the shed, you will see a long and narrow rectangular structure which appears to be a building housing a row of refrigeration compressors. This fits in with the theory that the fire apparently started in the West half of the building as indicated by the more extensive damage to that side and that this narrow structure or the ground floor of the RCC building adjacent to it housed the compressors.


Figure 11, 12. The East side of the building (the rear in Figure 5), serves for arrival of live birds In the above pictures you can see rescue attempts being made from one such bays after the firemen have knocked open the door from outside. The roof of the bay shelter (Figure 11) is gone, probably blown off and the heat signature on the sheet metal wall of Figure 12 shows that the insulation was on fire from within. Notice that this bay has a big plinth.

Figure 13. This picture gives a good idea of the roof height at the South end –some 6-7 metres. It also gives a good view of the prefab construction with fixed windows.

Figure 10 shows the mangled remains of a semi-automatic cut-up line called the “Japanese Cut-up Line” or the “J-Shackle Line” in the industry. A central belt conveyor stands immediately below an overhead conveyor line (“T” track - remains and ceiling supports for which are visible in the foreground) Arranged along both sides of the belt conveyor are rows of work platforms called Lady-Lane Trim Tops. However, these J Shackle Lines are not enough for the extensive product finishing carried out at this plant as Figure 9 shows lines of manual trimming and finishing tables arranged according to workflow.

5.4 Construction Materials - Sandwich Panels

Figure 13 shows some design details. Prefabricated RCC exterior walls with doors and windows, sandwich panels above that, joining it to the roof eaves. The most common cores in sandwich panel construction are expanded or cross-linked expanded polystyrene (EPS, EXPS), polyurethane (PUR), poly-iso-cyanurate foam (PIR), glass wool, mineral wool or rock fibre. EPS, PIR and PUR are all combustible.

Mineral, glass or rock wool systems with combustible adhesives or organic binders used to adhere the metal facings to the core are also combustible to some extent although they produce small amounts of energy in a fire. PIR's are fire retardant variants of polymer sandwich panels which "perversely tends to emit more and thicker smoke when they burn", says Prof J. Lygate[8], writing on June 11 about the incident. Besides carbon particles, smoke from PIR and PUR fires consist of hydrogen cyanide, oxides of nitrogen, and carbon monoxide, all of these being extremely toxic.

Figure 14. Taken from the East end, close to gate 2, this shows construction details. The sandwich panels in this and several other pictures have completely delaminated. Behind the main shed you can get a glimpse of the admin building and to the extreme left the row of buntings at the main gate.

The commonest criticisms of EPS panels in fire relate to the delaminating of the outer skins exposing the core and its failure to stay in place instead of collapsing and the fire spreading within the panel. Electric cables, which are placed over the false (drop) ceiling, come down with the collapsing panels. This is probably what happened at JBPPP, leading to power outage immediately after the fireball raged through the building. If there was an emergency lighting cabling, that also failed probably because its cabling also ran atop the panels.

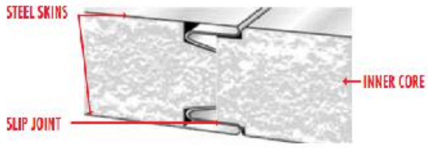


Figure 15: Diagram showing continuity of core material. Source: Insulated Panel Council Australasia Ltd (IPCA), which commenced development of a voluntary code in 2008 to deliver a better performing panel and increase fire-fighter confidence

It is fairly established that sandwich panels will not start fires, nor will they be the first to combust. They will burn when the panel delaminates and the core is exposed directly to flame. This happens readily in horizontally placed panels through thermal de-lamination of the sheets.

Once they ignite, the fire within the metal skins spreads undetected and rapidly (at 0.5 metre per second) through the polymer zone (which, the illustration in Figure 15 shows, forms a continuity through adjacent panels), reaching other parts of the building in a flash. And after a fire gets established within the sheets, extinguishing it is difficult as water jets cannot reach the combustion zone.

As part of its service to users of sandwich panels, the Insulated Panel Council Australasia Ltd (IPCA) has now put in place a voluntary industry code of practice to improve the performance of fire-retardant EPS panels. It is interesting that some of the research has been embarked upon by IPCA in conjunction with several Asian institutions including the City University of Hong Kong and University of Science and Technology of China.

Figure 16: A Quonset hut from the Second World War. Note the self supporting roof and door at the gable end

5.5 The Quonset Hut Design

Figures 23 and 24 show the position of out-buildings and structures. The buildings are of four basic designs – RCC multi-storey buildings, sloping steel sheet roof huts, unidentifiable structures and semi-circular self-supporting steel sheet roofs. Of the last named, there are two Quonset Huts (1 and 2 in Figure 23). The Quonset Hut design, of WW-2 vintage, was an improvement of the Nissen Hut first designed during WW-1. The design gets its name from the place where it was first constructed – Quonset Point in North Kingstown, Rhode Island, USA. It is meant to be temporary, cheap and quick to erect, but it falls short of an ideal when used as an industrial shed.

Figure 16 is a vintage picture of one such hut. Notice the semicircular top and absence of side walls, necessitating the construction of a dormer window for ventilation. It is my belief that this construction philosophy has influenced the design of several huts adjoining the main process shed at JBPPP. Note for instance, the light steel reinforcements of the roof in the product dispatch hut where it has been burnt off and the absence of doors (Figure 5) except at the gable end.

Figure 17: The burnt off roof of the finished goods dispatch shed abutting the main process shed at the West end. Note the wheeled trolley

5.6 Emergency Exits and Windows

Having examined the construction and layout details, we can now make an exhaustive listing of main doors. For goods movement: three at the West side, one on the North side and an unknown number of doors on the East side. Notice that the live bird delivery end shown in Figure 7 is being used for extraction of whole dressed carcasses. The arrival end ought not to have connection with the processed bird area, but it does – further attesting to the possibility of a variety of interconnections within the work space. For the entry - and presumably emergency exit of workers - there are four well defined doors on the South side as evident from Figures 14 and 23.

How many emergency exits are there? One door on the West side, not visible in Figure 5 (read also the text below Figure 5), three on the East side (Figures 18 and 19), maybe some on the North side for which we have no evidence, material dispatch and packing material receipt doors (3 nos) and of course all four doors on the South, provided they remained open. Exit is also possible through the dispatch bays and live bird arrival end and possible utility line service gates. There is also the likelihood that the normal exit to the canteen structure could serve as a getaway. But this gate would certainly be locked except at meal times.

Figures 18, 19 The first picture shows firefighters located in one of the bays formed by the several abutting sheds and structures to the East end of the main process area. The other picture, taken at the West end, before the entire wall was torn down as part of rescue efforts (Figure 5) shows some signs of fire and - a collapsed roof-gutter. This forms two possible emergency exits, one of them added as an afterthought – the height, shape and absence of protection against rain at this doorway suggesting that it opens not into the process area, but into an internally located utility area..

That brings us to windows. Buses and trains are required by law to have emergency exits. Some of the glass windows can be opened for passengers to escape in the event of accidents. In Figures 5, 6, 13, 14, 17 and 18, this plant appears to have a sufficient number of windows. Most of them remain intact, and almost all show signs of being hermetically sealed against the escape of smoke. Except for the placement of windows in the dispatch shed (Figure 5), which are too high for any escape attempt, most other windows could have been used for escape from the fire provided they could have been opened or smashed open. They were not: as evident from the photos, and none of them is broken, nor has any smoke traces.

What conclusions can we draw? Either the designers did not think of this or standard windows which can be used as emergency exits are dimensionally incompatible with jigs and dies available with the local manufacturers of precast concrete exteriors.

What was the most likely escape route? Almost certainly many workers escaped through the West side dispatch door. If the fire started in the main building near the North East end, and gradually worked its way into the front dispatch shed, then the progress of the fire followed the path of open doorways left by fleeing workers. What is the evidence? Figure 3 shows no smoke coming from the dispatch shed on the right – this picture being taken at the initial stages of the fire, while Figure 4 shows that workers escaping through this gate, probably leaving the interconnecting doors open, allowed the fire to follow them, completely gutting the dispatch shed by the time the fire died down, as shown in Figure 5.

Why does the South end not show any signs of fire? Or for that matter the East end? Probably because there were no open pathways for the fire to follow escaping workers (opened doorways) in these directions, or because there were not much combustible materials at these ends.

5.7 Refrigeration and Fresh Air Movement

In a large processing facility such as this, the use of a central refrigeration plant using ammonia is de rigueur[9]. When one relies on fluorocarbons, one can consider distributed compressor locations – but not with ammonia. Therefore, the one utility building you would expect to see close to the process shed, would be the central ammonia compressor hall. Considering the dimensions of the processing shed, and the generally ubiquitous requirement of refrigeration throughout its extent, cost effective placement of the central refrigeration plant close to an outside edge of the shed would not make sense. The most cost effective, but imprudent, location for it would of course be somewhere in the centre of the shed!

Do we see any evidence that the refrigeration plant was inside the process shed? Possibly - if the unmarked empty rectangular hall located between the two cut-up halls and just South of the grey box-like cold store in Figure 25 can be taken to be it. This location certainly appears to have the shortest distances to all sections requiring refrigeration - the water-chill bath (shown as a dark gray square), the two cut-up halls and the cold store. On the other hand, if this is not true, can we locate it outside the shed from any of the published photos? No. not really. I have only very tentatively suggested that in such a situation the likely location of the central compressor complex would be at the North East end

There are no roof-mounted air extractors on the right side of the building – the left side, having sustained more burn damage, clearly had two ridges to provide extraction and north-light. If one assumes that movement of air out of the building is not natural but directed entirely on forced basis, then one must either ascertain or eliminate the possibility of wells (or shafts open to the sky) within the building. The aerial photograph in Figure 5 shows none, as does the Google map illustration in Figure 23. Air intakes, if they existed, can therefore be inferred to have been placed along the eaves. But as the majority of eaves have been dismantled, we can not be certain of this.

5.8 The Square Steel Building Layout Mindset

Factory buildings and many public spaces such as shopping plazas and malls are now increasingly designed around steel frame, corrugated steel roofs on trusses, prefabricated concrete exterior walls with built-in door and window openings, and sandwich panels for internal walls and false (drop) ceilings.

For such constructions, structural engineers instinctively favour square plinths because it saves them a lot of design time even while they tom-tom the virtues of exterior surface area to volume ratio – i.e. high thermal efficiency – whether internal areas are to be cooled or heated, as necessitated by process conditions.

What are the facts? In a square design the designer encounters a lower degree of freedom to change the building's side dimension than in a rectangular design - you cannot change the dimension of one side without simultaneously changing the dimension of all four sides. A square plinth also increases the distance between utilities such as a central refrigeration plant and target refrigeration zones within the building. So some of the savings in the building's so called thermal efficiency does get neutralized – for example in increased pump load in the refrigeration circuit. Additionally, for buildings which make extensive use of ammonia as refrigerant and install large amounts of sandwich panels in the interior, making *buildings within buildings* as it were, as commonly done in the food processing industry, not only do distances to exit increase, but a greater potential exits for pockets to trap ammonia between the false (drop) ceiling and the roof sheet and elsewhere.

Further, once the structural imperative of square building is a given, the process flow is required to fold back and forth in a zigzag fashion until it is forced to fit into available spaces. Remember - the layout principle in slaughterhouse design follows a cardinal rule – the dirtiest areas are always placed farthest from cleanest areas. Any attempt at repeated folding of process flow ignores this rule. To make amends designers then resort to complicated air flow routes, completely compartmentalizing certain sections in the effort and creating more pockets for leaked ammonia to get into and stay trapped.

Does a square building actually make a compact design, reducing the need for outlying external work spaces? I think not - take a look at the reconstructed layout in Figure 23. Seven or more structures were added at the East end to accommodate diverse plant functions that were probably not suitable within it.

Here the workers' entry gates on the South side requires workers to also exit from these gates – all other gates have different functions. Imagine the complex exit routes when you consider that the straight distance into this 120m x 140m building could be as much as 100-150 metres, and that the actual escape distances could be twice or thrice that amount because of zigzag placement of work flow. All these things result in a more hazard-prone design.

For comparison purposes, the heat efficiency of a building may be considered a function of its external surface area. You would instinctively imagine that a square building would have significantly less surface area than an equivalent building having a rectangular shape, given that their heights and material of construction are similar.

To test this hypothesis in the context of this study, I made a comparison of two different building styles suited for complete processing of 12,000 birds per hour. This comparison is presented in Figure 22. The square design is based on a real, existing, poultry slaughterhouse. The modular design is my variant.

If we assume that both versions have an average height of 8.5 metres, then the external surface area of the modular version is actually only 5.6% more, even as its plinth area (usable space) is also higher by 5.5% in comparison with the square version!

But in actual fact, the average height of the square version would be more than 8.5 metres because of its greater length, necessitating a higher peak, given the same roof slope, and so its surface area advantage would further diminish.

Then there are other issues to consider. In the modular design, the placement of parallel corridors provides shorter distances to exit, reduced number of consecutive doors to negotiate during exit, more usable space within the building through use of corridors that can become the preferred locations for columns (resulting in higher thermal efficiency, as more columns can be placed outside the coldest areas) and shorter tie-beams between columns, which would further reduce construction cost.

You will also note in this comparison that the size of some of the functional areas in the compact design have been made larger than necessary by the designer simply because there was nothing better to do with the left-over space. Consider, for example, the unnecessarily large external access frontage and area of the ingredients store!

But most importantly, in the context of this report, more corridors in the modular design mean more potential emergency exits and more and shorter escape routes. In other words, by deviating from the conventional wisdom of square buildings, the modular variant presents an overwhelmingly safer, cheaper and better industrial building design.

6.0 Epilogue - Some Generalizations for the Specific Sector

My experience as a consultant in the third world is that customers do not like to pay for consultation and technical counselling. This is a deep-rooted cultural malaise. The responsibility for eventual technical and safety suitability of a workplace is on "…others, whom we are paying so handsomely for equipment and technology!". In other words – implicitly the process equipment suppliers, who, in their eagerness to sell, make sweeping claims. Such a promise or dependency may not be legally enforceable, but it is difficult to dispel this notion as it constitutes a piece of cultural baggage.

Figures 20, 21. The first picture of the interior of the building, shows thermally insulated refrigeration piping and. rescue workers are cutting away something. Guy wire stays suggest this may not be a normally accessible section or work area. In the second picture rescue workers are somewhere close to the high ridge, which, judging from their height, appears to be around 13-15 metres. Note the delaminated false (drop) ceiling sandwich panels still hanging at approximately 6 metres height.

Do, or rather, can, leading technology sources actually deliver against this implicit understanding? Or are customers in the third world eventually left to their own devices to obtain technical assistance from *other* suppliers, typically the more aggressive sellers of construction materials, such as, in this case, panel suppliers polystyrene sandwich panels? Once again, “free of cost”? And what does this approach end up eventually costing customers and employees?

I believe, embedded within this unfortunate incident are caveats for everyone involved in the business of creating poultry processing plant design, constructing such plants and selling or providing machinery and technology to this sector. To sum up,

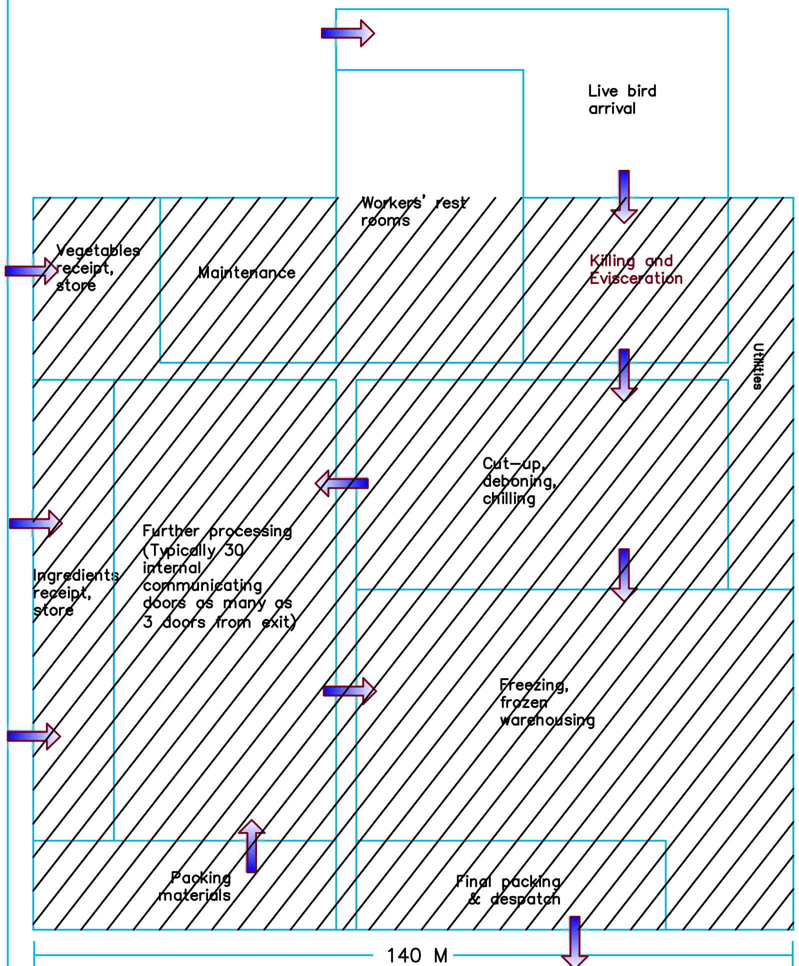
1 Technology and cultural milieu must be in synchrony. Culture is a slow moving, lumbering entity. Where technology remains alien or falls short of being fully absorbed, culture short circuits it and ends up with the worst of both worlds.

2 The smart consulting designer picks and chooses, striking a delicate balance between the fruits of technology, the caveats of legislation and standards and the limitations of local culture.

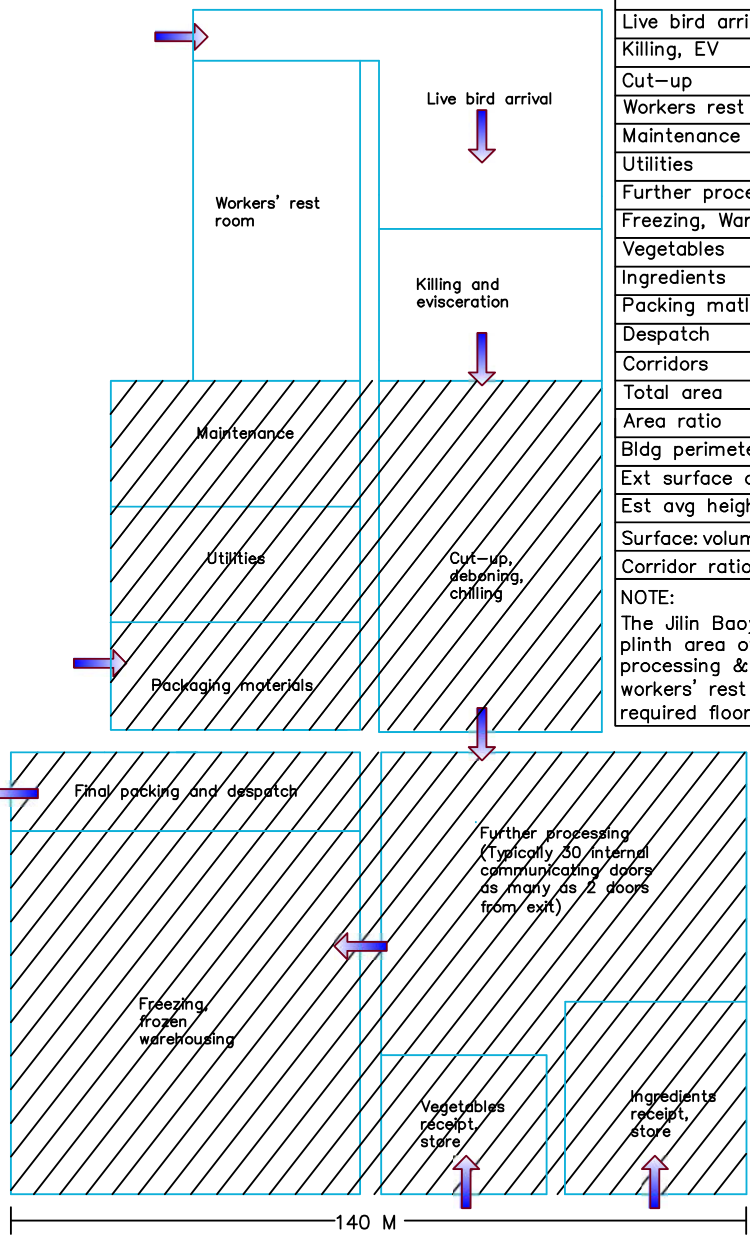
3 Though he may not know the details, the smart salesman is aware of this delicate balance. He is never aggressive, just circumspect when making promises.

4 For the markets it operates in and hopes to build a durable presence in, the smart management is aware of all these. After all, it knows that globalization also means a world where a stepladder that does not carry a caveat against incorrect use, can land it in trouble.

For industrial plants in general in the food processing sector and authorities entrusted with the task of implementing standards and codes for industrial and public safety, the caveats that emerge from this analysis are the subject matter for the second part of this report, to be uploaded on this website shortly



Layout based on square box building with total area 23005 SqM



Layout based on modular rectangular box steel building with total area 24050 SqM

Functional area	Square design	Modular design
Live bird arrival	1840 SqM	2130 SqM
Killing, EV	1220 SqM	1230 SqM
Cut-up	2840 SqM	2850 SqM
Workers rest	1990 SqM	1950 SqM
Maintenance	1050 SqM	1140 SqM
Utilities	900 SqM	1050 SqM
Further process	3730 SqM	3680 SqM
Freezing, Wareh.	4440 SqM	4630 SqM
Vegetables	840 SqM	840 SqM
Ingredients	1350 SqM	1270 SqM
Packing matl.	980 SqM	980 SqM
Despatch	1000 SqM	1000 SqM
Corridors	820 SqM	1300 SqM
Total area	23000 SqM	24050 SqM
Area ratio	1.000	1.054
Bldg perimeter	642 M	732 M
Ext surface area	53224 SqM	54322 SqM
Est avg height	8500mm	8500mm
Surface: volume	1.000	1.056
Corridor ratio	1.000	1.58

NOTE:
The Jilin Baoyuanfeng main shed likely has a plinth area of 17000 sqM. Assuming it was processing & portioning 12000 BPH, and had workers' rest rooms within this shed, the required floor area = +/− 16000 SqM.

Figure 22 – Square Design Compared to Modular: Is Square Design Justified At All?

APTEC
Project: Report on the Jilin Baoyuanfeng poultry plant fire, June 3, 2013
Capacity: 12000
Drawn by: Alok Raj
Title: Comparison of square & modular layout philosophies
Date: 19/07/13
Drawing no.: GEN 097.01

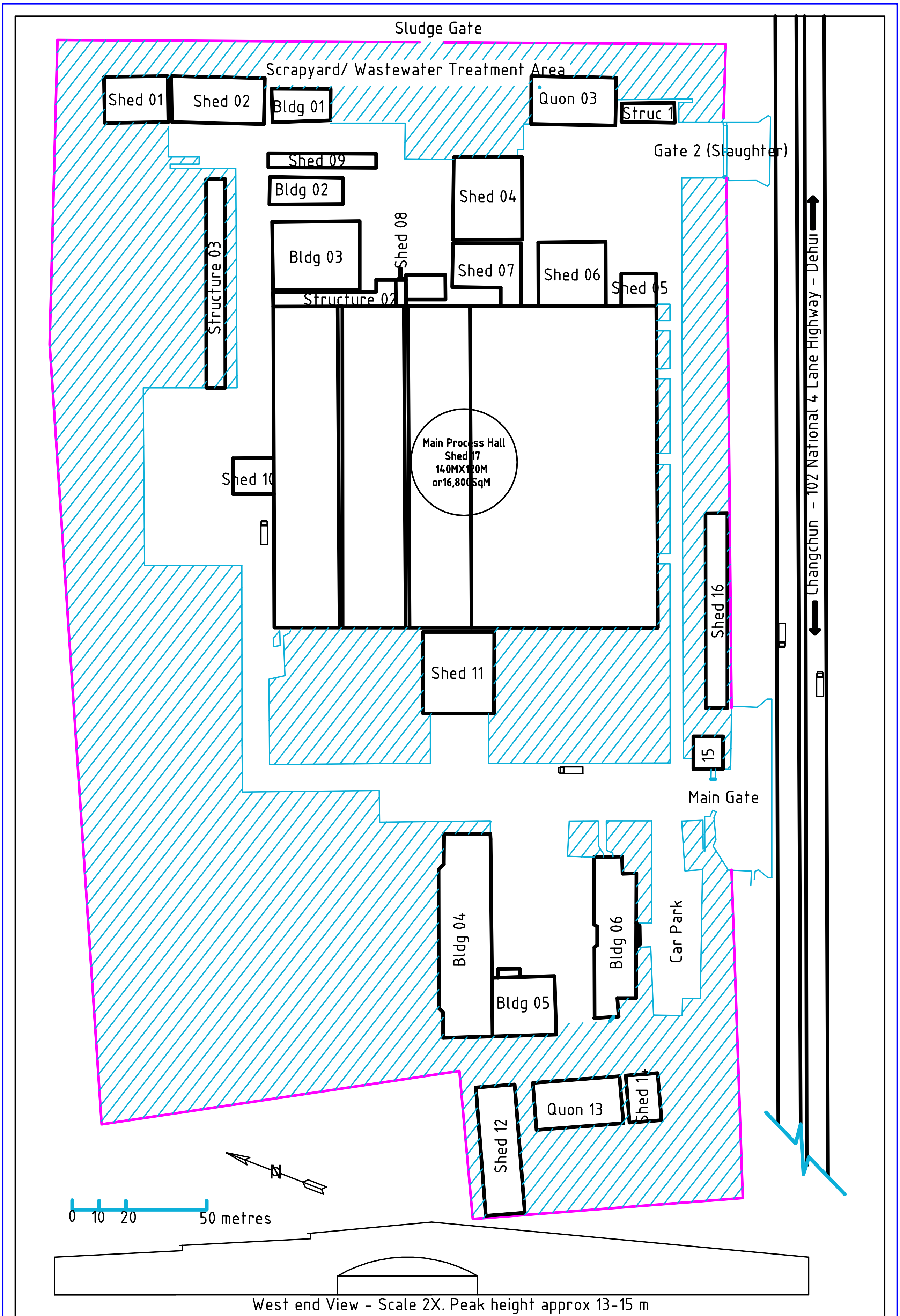


Figure 23 -Jilin Baoyuanfeng Poultry Processing Plant, imported into Autocad and traced from 100 M scale Google Map.

Figure 24. Google Map taken at coordinates 44.136184,125.487696 showing the Jilin Baoyuanfeng Plant

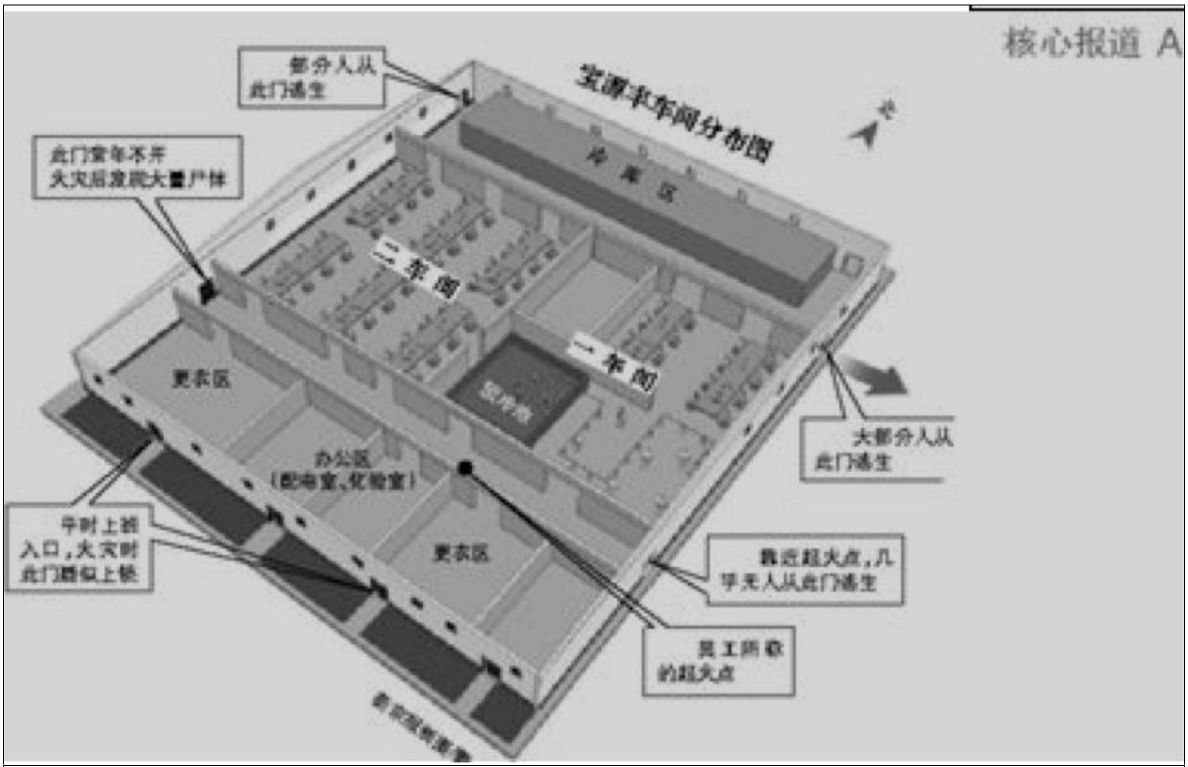


Figure 25. I came across this picture at the fag end of my writing and while this find could not be adequately used in my analysis, it did serve as a check to some of my conclusions. I cannot read the text, but my surmise about the presence of four doors to the South, the existence of live bird arrival at the East, and the presence of a warehouse on the North side and some other details are corroborated here. It is also possible that the empty rectangle just below the oblong cold store along the top edge is the central ammonia refrigeration plant – such a hypothesis would tend to support the position of dense smoke exiting the building at the commencement of the fire, as shown in Figures 3 and 4 and fit the shortest distance condition to the two cut-up halls flanking it, the cold store and the dark squarish water chill area just below it.

Disclaimer: The author, Alok Raj, is Director APTEC, a company involved in design and consulting work for the processed foods, poultry and meat processing industries in South Asia. He may be reached at +919811049914 or alok@aptec.in The views expressed here are in the interest of the industry and do not necessarily reflect ideas or interpretations attributable to any person or organisation. In so much as readers seek to excerpt sections of this article for discussion or dissemination, provided always that they acknowledge the original source(s), they are free to do so even as much as the Author does himself quote, with acknowledgement and thanks, data, views and ideas from within the public domain. Readers are welcome to send their comments, critiques, observations and suggestions to the author at alok@aptec.in

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[1] (a) Hamlet Chicken Processing Plant Fire www.rorigas.com/hamlet-chicken-processing-plant-fire-2013-06.html 3 Sept, 1991; (b) Hamlet Chicken Processing Plant Fire worldhistoryproject.org/1991/9/3/hamlet-chicken-processing-plant-fire; and videos on YouTube (c) Mojo Nixon and Jello Biafra ~ Hamlet Chicken Plant Disaster http://www.youtube.com/watch?v=xyU-PvbOjlo; (d) Hamlet: The Untold Tragedy 1994 Robert Cotter http://www.youtube.com/watch?v=9G5dWMXz8V8

[2] Report 057 entitled Chicken Processing Plant Fires - Hamlet, North Carolina and North Little Rock, Arkansas of the Major Fires Investigation Project conducted by TriData Corporation under contract to the United States Fire Administration, Federal Emergency Management Agency, USFA Web site at http:// www.usfa.dhs.gov/

[3] IFIC Forensics – The Dangers of Sandwich Panel Buildings, June 11, 2013, by Professor James Lygate Principal Investigator at IFIC Forensics and Visiting Professor of Fire Investigation at the University of Edinburgh. Info @peak-marketing.co.uk. Also published on Insurance Insight http://www.insuranceinsight.com/ as Sandwich Panel Construction

[4] Such a plant effectively works round the clock. An explanation of effective shifts is given in Figures 9, 10

[5] Deadly fire in China's poultry plant sparks workplace safety concerns, excerpted from chinadaily.com.cn, Updated: 04 Jun 2013, http://www.whatsonningbo.com/

[6] The eight sources referenced above are:
A -Many Still Trapped in China's Poultry Plant Fire, World-3 News, 4 June, 2013

B -Lax Safety Blamed in China Poultry-Plant Fire China News June 6, 2013, 10:49 a.m. ET By James T. Areddy
C -Weibo Reacts To China Jilin Poultry Factory Fire, Calls For Resignation Of Factory Owner By Michelle Florcruz on June 03 2013 1:23 PM
D -Bill Stevenson, The Wall Street Journal, June 6, 2013–Lax Safety Blamed in China's Poultry Plant Fire
E -Christopher Bodeen, Huff Post Business, June 28, 2013 China Poultry Plant's Locked Doors Highlight Work-Safety Concerns
F -Chinese Poultry Plant Fire Kills 119 – Dave Fusaro, Food Processing, 28 June, 2013
G -Jilin poultry plant fire kills 120 CCTV News - 3/6/2013 CNTV English
H -Wikipedia

[7] A Quonset hut is a lightweight prefabricated structure of corrugated galvanized steel having a semicircular cross-section. The design was based on the Nissen hut developed by the British during World War I. The name comes from their site of first manufacture, Quonset Point, at the Davisville Naval Construction Battalion Center in Davisville (a village located within the town of North Kingstown, Rhode Island, USA).

[8] Ibid

[9] A vast amount of comparative literature on efficiency, economy and safety aspects of ammonia versus fluorocarbons exists in the public domain. Each side argues its case energetically - one extolling the virtues of ammonia and the other highlighting the safety of variants of fluorocarbon refrigerants. That ammonia is toxic and combustible in large concentrations are never denied by either side. But the jury is already in – for large industrial applications ammonia is, and remains, the refrigerant of choice worldwide till technological developments allow us to use ordinary air as its final replacement.

Acknowledgement of Pictures from the news media used in this report.

Figure 1 World History Project - Hamlet Chicken Processing Plant Fire , worldhistoryproject.org/1991/9/3/hamlet-chicken-processing plant-fire
Figure 2 Hamlet Chicken Processing Plant Fire worldhistoryproject.org/1991/9/3/hamlet-chicken-processing-plant-fire; and videos on YouTube
Figure 3 Chinese Chicken Farm Fire Kills At Least 100 Workers. Video on Youtube http://www.youtube.com/watch?v=O5jcByLxW2E
Figure 4 119 Dead in China's Deadliest Blaze in 13 Years, http://www.businessweek.com/videos/2013-06-04/119-dead-in-chinas-deadliest-blaze-in-13-years
Figure 5 Locked doors at torched poultry plant show how little has changed for many Chinese workers By Christopher Bodeen, The Associated Press, June 5, 2013 http://www.montrealgazette.com
Figure 6 WWW.News.cn. http://www.google.co.in/imgres?q=jilin+poultry+fire&start=100&sa=X&biw=1246&bih=658&tbm=isch&tbnid=5W5apJhogTynnM:&imgrefurl=http://www.militaryphotos.net/forums/showthread.php%3F227236-112-people-dead-in-A-fire-in-China&docid=DFu9fC5zMdKvhM&imgurl=http://i.imgur.com/9GxP9vg.jpg&w=900&h=499&ei=lvLQUbD5LcGIrQf1sYCgAQ&zoom=1&ved=1t:3588,r:31,s:100,i:97
Figure 7 http://www.scmp.com/news/china/article/1254757/two-executives-jilin-poultry-plant-arrested-over-chinas-deadliest-blaze
Figure 8 A Crowd Gathers to watch as firefighters search for survivors at the Baoyuan poultry plant that caught fire in Dehui, north-east China's Jilin province, on June 3, 2013. -- PHOTO: AFP http://www.straitstimes.com/breaking-news/asia/story/jilin-fire-survivors-describe-sea-flames-chaos-20130604
Figure 9 Workplace tragedies challenge 'Safe China' By Xinhua writer Li Laifang (Xinhua) 08:07, June 04, 2013 http://english.peopledaily.com.cn/90882/8269248.html
Figure 10 The fire damaged poultry factory building… http://www.channelnewsasia.com/news/asiapacific/two-arrested-after-deadly/699790.html
Figure 11 http://news.yahoo.com/lightbox/firefighters-try-extinguish-fire-poultry-slaughterhouse-dehui-photo-014411250.html
Figure 12 http://www.stasiareport.com/breaking-news/asia/story/jilin-fire-panicked-workers-scrambled-single-open-exit-say-survivors-201306 Jilin fire: Panicked workers scrambled for single open exit, say survivors Published on Jun 04, 2013 9:43 AM
Figure 13 Fire kills 119 at poultry plant in northeast China Christopher Bodeen Associated Press From The Detroit News: http://www.detroitnews.com/article/20130603/NATION/306030341#ixzz2ZwyruvCX
Figure 14 Jilin fire: China poultry plant workers didn't query locked doors, even after previous fire Published on Jun 05, 2013 http://www.stasiareport.com/the-big-story/asia-report/china/story/jilin-fire-china-poultry-plant-workers-didnt-query-locked-door#sthash.sRaBMmMA.dpuf
Figure 15 Building Australia's Future 2011Conference EXPANDED POLYSTYRENE SANDWICH PANELS CODE OF PRACTICE Industry Working Collaboratively to Develop No-Regulatory Solutions Version 2.0 John Clampett – John Clampett Consulting Ron Lawson – CEO insulated Panel Council Australasia Ltd
Figure 16 Wikimedia Pictures commons.wikimedia.org/wiki/Category:Quonset_huts American troops marching to quarters in Ireland 1942-02.jpg
Figure 17 http://news.in.msn.com/topstoriesarchive.aspx
Figure 18 Relatives scuffle with police after China fire kills 120 June 04, 2013 11:16 AM By Maxim Duncan http://www.dailystar.com.lb/News/International/2013/Jun-04/219375-relatives-scuffle-with-police-after-china-fire-kills-120.ashx#ixzz2Zx3OJ3M1 (The Daily Star :: Lebanon News :: http://www.dailystar.com.lb)
Figure 19 Death toll rises to 112 in NE China fire (Xinhua) 15:32, June 03, 2013
Figure 20 China fire survivors tell of 'sea of flames' http://news.ph.msn.com/top-stories/china-fire-survivors-tell-of-sea-of-flames-6
Figure 21 www.whatsosanya.com/news_images/798401Jilin-plant-fire
Figure 25 Dehui fire Shame: Flammable materials substandard (2) Published: 2:39:46 June 13, 2013 http://www.best-news.us/