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Poultry Slaughterhouse Design – Materials & Safety : Lessons From Slaughterhouse Fires

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Preface

The original article entitled ***What Happened at Jilin Baoyuanfeng*** (WHAJB), on which this present one is based, was posted on the Aptec website around July 2013. The article was about the great fire at a poultry slaughterhouse in Mishazi, Jilin Province of China, in Manchuria, on June 3 of that year. The fire created global consternation and a media stir for several months. Aptec was then the Indian representative of Meyn Food Processing Technology B.V. of The Netherlands and was involved in design of poultry slaughterhouses for India, its neighbouring countries and elsewhere. This event therefore held much relevance for Aptec.

WHAJB, the article, was written for an audience already familiar with poultry processing and was circulated within Meyn Holland, its subsidiaries and overseas offices by the management, which believed it to be an important reference document for designers. Aptec got feedback from some poultry slaughterhouse owners in South Asia to the effect that on reading the article they had made modifications to their buildings in the interest of workers' safety. Much later, the lessons learnt from WHAJB were once again in wide discussion in India when a fire occurred at a slaughterhouse which was under construction in Tamil Nadu in July 2021 based on plans supplied by Marel, a world leading vendor of poultry processing equipment, headquartered in Iceland.

Throughout the past decade, there was no communication from China. But then we did not expect any, given the language barrier. Meanwhile, unknown to us, someone in China had come across WHAJB on the internet, and displaying a great deal of foresight, had downloaded and saved a copy.

So it was, that when the Chinese authorities approached Dr Andy Pearson, Group Managing Director of Star Refrigeration Ltd, UK, and a member of ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), in 2022, to look into the event, they handed him a copy of that saved article. Dr Pearson read it and in turn contacted Aptec in November 2022 with queries. Aptec was able and happy to share further information and backup references, and discuss the matter through an exchange of e-mail.

In 2018, this author retired from the position he held as Meyn's sales and technical representative in India. After that, based on his long association with the field, he continued consulting in the design of poultry slaughterhouses and other meat processing facilities. He also decided to use his retirement gainfully to write a handbook on the subject for the benefit of the industry.

This chapter is a part of that effort. It re-tells the original WHAJB story as it relates to the topic *Design of Poultry Slaughterhouse – Materials and Safety,* written in a style more suited to the layman as it may be read by persons unfamiliar with poultry processing. Its companion chapters on *Layout, Geometry & Construction Methods* and *Ventilation and Lighting* are also to ne uploaded on the Aptec website in mid 2023. As regards this chapter, Dr Pearson has offered to contribute his observations in the form of an epilogue. Aptec is grateful for the help offered by him. It is also our hope that this re-telling of the Jilin Baoyuanfeng fire, complete with explanations about plant design, features, operation and conventions, explained by an industry insider in a style suited to the lay person, would complement Dr Pearson's own presentation of the event at ASHRAE's International Congress of Refrigeration to be held in Paris in August 2023 and form a case study for readers of the Aptec Handbook on Poultry Slaughterhouse Design.

1.0 Déjà Vu

On 3 September, 1991, in the North Carolina town of Hamlet, USA, a fire in a poultry ready-to-eat (RTE) products plant, owned by Imperial Foods, killed 25 workers. The story is detailed in videos, text reports and a song on the internet[1] . In the light of these, the Jilin event evoked in us a deep sense of déjà vu. Workers at Jilin Baoyuanfeng poultry processing plant (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 work-flow lines, boarded or otherwise shuttered windows to prevent theft of chicken, insufficient safety inspections or compliance, lack of safety drills, narrow corridors, poorly marked or blocked emergency exits, toxic thick black smoke from the combustion of thermal insulation and power blackout – they were all common to both tragedies!

But between these events there were differences, too. The Hamlet plant building 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 SqM. It 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 probable impression was that such plants did not contain much inflammable stuff except for some packing materials. But a fire did take place, and it was traced to the jerry-rigged hose connector of the hydraulic oil heating system in a Stein fryer[2]. And, unknown to them in those days, partition walls (probably made of sandwich panels) were also combustible.

Figures 1, 2 Imperial Foods Plant at Hamlet before the fire; drop ceiling is barely over 3 metres high.

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 through the internet, but was apparently ignored by the designers or glossed over by the owner. In the JBPPP fire 395 workers were trapped[3]. And the fire occurred in a modern steel, concrete, brick and sandwich panel shed having a total of nearly **17,000 square metres floor area - 1.7 hectares, or six times as big as Hamlet.** This made speedy escape many times more difficult and time-consuming than at Hamlet.

A month after the earlier mentioned Hamlet fire, 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[4], caught fire. This time there were no fatalities, but the similarities between these events were uncanny. The US Fire Administration's report 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 SOPs put in place by Tyson. So although since 1991 there have been many fires in poultry processing facilities worldwide (see a representative list in table 42), they have had minimum fatalities.

Poultry processing is rapidly becoming mechanized and institutionalized in the third world. The JBPPP fire should be a wake-up call for all such third world developments. We also need to know 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[5]. All this has serious implications for not only designers and consultants but also leading suppliers of systems and equipment for the processing industry.

Based on this and subsequent fires listed in table 42 Aptec has compiled a comprehensive safety drill to be used when planning sandwich panel constructions, carrying out such constructions or operating plants which incorporate such construction and/or are to be used in association with ammonia based refrigeration. This compilation of safety procedures is available in table 44

2.0 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 incorrect report that JBPPP was owned by one of the important processors in the Dehui area - the leading processor Jilin Deda (Charoen Pokphand or CP). Compared to Jilin Deda, JBPPP was much smaller.

Figures 3, 4 The upper picture shows a probable packing material receipt gate (D1 of figures 7, 10). The brick wall in figure 14 is apparently behind the sheet steel-dado wall seen here. The bottom picture, taken from across the highway near the main gate area, shows the admin building on the left.

JBPPP was a new green-field processing plant set up in 2009, designed to process 12,000 birds per hour (BPH) probably on 2 shift basis[6], to account for some 67,000 tonnes (2010 official data on the company's website) of processed chicken per year[7], for which it employed 1200 workers (although only 411 of them had signed formal work contracts)[8]. 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 reported an official sales volume of $38 million[9]. But an April 2013 job advertisement online posting says the company had grown to $58.7 million sale in 2011 and was, at that time, hiring 200 additional workers[10]. 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 variety) putting her poultry processing infrastructure under strain[11]. So it is conceivable that this plant's unofficial capacity may have been higher than the official figure.

The plant probably ran round the clock, with two primary shifts comprising slaughter - going all the way up to water chilling of carcasses, of 8-9 hours each and three secondary processing shifts (cut-up, de-boning and packing). This would make 5 work shifts in all, or considering that the primary slaughter shift requires less manpower, four roughly equivalent manpower shifts of approximately 300 persons each[12]. So for some 18 hours per day the maximum number of workers inside would be approximately 425. For the remainder the number would be approximately 330. In this way the plant would run round the clock, with possible overlaps between production shifts, and a couple of hours of cleaning between them – probably twice a day. See Table 9 for a reconstruction of manpower deployed at the plant.

Figure 5 A pack of chicken popcorn. The picture was downloaded from the internet during the wave of news items concerning the Jilin Baoyuanfeng event. What does the Chinese text say?

Our databank contains only one picture, apparently showing packaged RTE food (chicken popcorn), implicitly produced at this facility[13]. We are unable to find anything to support our assumption, so this amounts to weak and inconclusive evidence about the facility producing RTE products. Save for placing here a picture of that supposed chicken popcorn pack as figure 5, we will therefore assume that this facility did not produce any RTE poultry, but restricted itself to raw poultry meat only. We add some details about this product here: Chicken popcorn is made from small (12-15mm sided) cubes of breast meat twice battered and twice coated, the final coat being Panko bread crumbs and deep fried. When done at an industrial scale one would employ a fryer similar to the Stein fryer mentioned above in connection with the Hamlet story. When done on a smaller scale, one would employ a wok heated by an LPG stove. But typically RTE products are not produced in a chicken processing shed – if one needs to do it on the same premises, one locates the RTE facility in a separate, adjacent building and restricts cross traffic between raw chicken and RTE production areas for consumer health reasons.

2.1 The Incident

At 0606 hrs on June 3, 2013, as the plant was undergoing a shift change, reportedly an electric short circuit created three large explosions which were followed by a fireball that set the plant ablaze. At that time there were some 395 workers on site[14]. 121 were killed, 77 hospitalized, with most of them being treated for smoke-induced injuries[15]. The fire raged the entire day, till mid-day the next - a video shot in the evening shows the west end of the building ablaze while workers manually rescue cartons of poultry (figure 14). News reports said that an electric fire in a workers' rest area ignited a concentration of leaked ammonia. Consistent with this news item, a Chinese news agency called Caixin published a diagrammatic representation of the internal arrangement within the main production shed and faithfully marked the probable origin of the fire within a workers' rest room area. This diagram is presented here as figure 31.

The fireball from these alleged electrical explosions raced through the processing hall (cut-up, de-boning and packing hall, referred here as the secondary processing area or workshop 2) rapidly (within 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 exit routes.

The accident was neither notified by an audible alarm, nor were the passageways lit up by any kind of emergency lighting systems. If they at all existed, air extraction systems or negative air flow systems, automatically operable in the event of an accidental ammonia release, 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/or failure of lights. To add to the mayhem, the complicated layout, inadequate and inconveniently placed exits, and locked exits resulted in lots of deaths. Lessons had not been leant - according to one worker there was an earlier fire three years ago, "ignited by a cigarette"[16]. Smoking on the premises was strictly forbidden. So if a breach did occur three years ago, the only place where it could have occurred would be the workers' rest rooms.

Shortly after the incident the communist party executives got busy handling complaints and apportioning responsibility for the incident. A report on the accident issued on July 11 by the State Council said that Zhang Dexiang, the Communist Party secretary and mayor of Dehui would be removed from office and another 22 officials would be punished. The report blamed the accident on a short circuit that triggered explosions of ammonia pipes. Other reports said that the fire also spread along flammable insulation. Loss of life was compounded by a lack of fire alarms, escape training, and locked doors. Secondary causes were attributed to unsafe production by the company, which suffered a series of fires in 2010 and allegedly falsified fire safety records. The city's construction, production safety and fire prevention authorities were found guilty of inadequate inspection.

Looked at in international perspective for the meat industry, 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 lacklustre performance of the pork market in USA. Recent news of deliberations over this deal indicate that the main American 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[17].

2.2 Stated Causes of the Incident

To make our analysis, we carefully examined eight independent news stories and a Wikipedia write-up[18] in the public domain. There are many others, but they essentially repeat earlier stories. We then made a frequency distribution study of stated causes of the disaster or causes leading to it. Based on the emerging evidence we then scrutinized over 70 photographs downloaded from Google's graphic store to reconstruct the event and draw inferences. These are presented in table 6.

	Table 6 – Reported Causes of the June 3 Incident	
	Possible causes, design, behavioural & operational shortcomings, culled from nine independent published accounts	
1	**How The Fire Originated**	**Inference**
1.1	Fire may have originated in a locker room	Strong evidence against this conclusion, except by special pleading suggesting presence of an explosively combustible gas
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, strong evidence against this hypothesis
1.4	Ammonia gas leak	Ammonia designing
1.5	Three large explosions were followed by a fire. One witness said she heard a huge blast and thought there was an earthquake	**
2	**Local Community Involvement and Response**	
2.1	Collateral injuries in adjacent township	Facilities, workers' hostel nearby
2.2	120 died, approximately 100 escaped, some 60 of whom received injuries. 3000 residents of nearby town 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 on two sides, a sheet steel wall on the other two sides and a corrugated iron roof with insulating sandwich panel, false ceiling and wall insulations and plenty of partitioned internal workrooms	Inconclusive *per se*, construction details analysed in section 4
3.2	Plant built with combustible materials	Sandwich panels
3.3	No one had time to use fire extinguishers	Analysed here
3.4	Fire engulfed the building in 3 minutes	Fireball from seat of fire
3.5	Inhalation of toxic gas	Analysed here
3.6	Struggled *through smoke and flames* to reach exit	Analysed here
4	**Layout Details**	
4.1	Cluttered layout	Analysed here
4.2	Had too few escape routes	Analysed here
4.3	Narrow and cramped exit routes	Analysed here
4.4	People trampled each other in their bid to exit through the single open door	Analysed here
4.5	Employs 1200 workers, but only 350 were believed to be at the site at the time of the fire	Analysed here
4.6	In a similar accident, workers' dormitory, factory and product warehouse were in the same building	Analysed here
4.7	200 tonnes of chicken/day. Or 12,000 birds slaughtered/hour, 2 shifts per day	Layout, capacity reviewed
4.8	Tight layout inside the plant	Analysed here
4.9	High number of employees – high manpower density	Analysed here
4.10	Some doors were too far to reach	Analysed here
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	Analysed here
4.12	Stampede ensued	Analysed here
5	**Absent Safety Features**	
5.1	Panic evacuation follows someone shouting "Run away!", not an alarm siren as one would expect.	Design. Analysed here
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. Analysed
5.7	The lights went out, causing panic and stampede	Design - cable positioning. Analysed
5.8	Power was cut off after the fire started	Design - cable positioning. Analysed
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. Analysed
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. Analysed
6.6	Emergency exit at workstation could not be opened	Design. Analysed
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. No comment
8.2	Chinese workers cannot effectively unionize	Special point. No comment
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.

Some of these observations are important for this report as they relate to safety, design and behavioural aspects. We cover them here. Others that relate to social and political factors are beyond the scope of this report and have not been examined.

There are many references to the occurrence of three explosions and the fireball at around 6 AM when the shift was changing. It was a summer morning and by 6 AM many would have been awake and would have heard the explosions. Many people lived quite close to the plant – probably in buildings 01 and 02 (see figure 7). Nearby residents had to be evacuated due to ammonia leakage. Of the deaths nearly 90% were women[19]. We revert to these points in the following review and in section 5 where we finally evaluate every probable cause of the fire.

3.0 Reconstruction Of The Facility

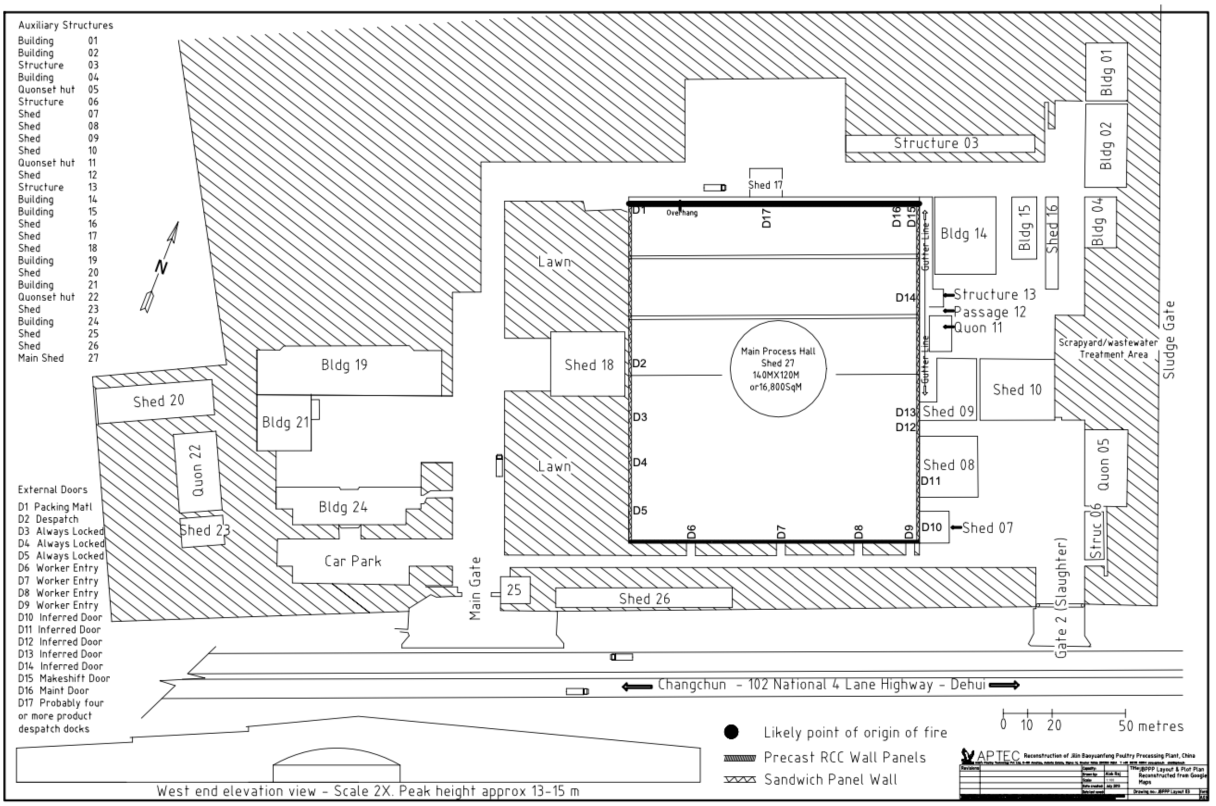


Figure 7 Reconstruction Of The Jilin Baoyuanfeng Poultry Processing Plant Plot Plan (traced from an import of a 100M Google map into Autocad). All building, door and feature numbers mentioned in this report follow those given in this drawing.

With the help of Google Maps, plausibility checks and a careful examination of over 70 photographs, we were able to create an Autocad drawing of the plant. This drawing has been presented in figures 7 and 10. Such a traced Autocad 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 possible re-evaluation of our analysis by other design professionals. We would welcome alternative interpretations and views. The particular Google map view that supplied the bulk of this tracing opportunity is available in figure 33. Throughout this report all features of the plant follow the numbering and naming convention established in figure 7 and repeated in figure 10.

3.1 Main Features

Towards the west end, behind the three multi-storey administrative buildings (19, 21, 24 – check out their location in figure 7) and the parking lots, are three huts (sheds 20, 22 & Quonset hut 23- see section 4.2), probably hostels and dining hall for essential senior staff. Near the main gate lies a time-keeper or security guard hut (25), and behind it, within a green belt, is a long blue motorcycle shed (shed 26). The south end of the main process shed also shows four pathways for workers' entry into it. These connect to four doors D6 to D9 and possibly also to rooms behind doors D10 and D11, which appear to be later additions, necessitated by expansions in plant capacity. The original layout probably had not envisaged either (a) such a severe shortage of space, or (b) such a large unplanned increase in manpower deployment, or (c) a choice of labour intensive technologies, which in turn placed a premium on space and manpower, specially for primary processing stages. In our opinion this led to a poorly designed mushrooming of sheds, buildings and structures on the east side of the main process building.

This mushrooming on the east end can only be catalogued and interpreted by an analysis of work flow.

Figure 8 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, just beyond the central ridge, remained substantially intact. Except for shed 18 in the centre and the secondary packing material receipt door (D1) on the extreme left, there were three other doors (D3, D4, D5) along the west wall, on the south of shed 18, which were destroyed as a result of rescue activities. These three doors were locked – the lawn giving ample testimony to this fact by bearing no signs of footpaths, although light traffic along the plinth protection might still have been possible. Going from left to right in the background of this picture (or along the east end), are three buildings (Buildings 01, 02 and 04), an intact smokestack arising from the vicinity of buildings 14 and 15, a truncated smokestack arising from the vicinity of sheds 08 and 09, the gable-end view of shed 08, the blue-domed Quonset hut 5 (housing the effluent treatment plant) and the gate for entry of trucks carrying live chicken. The truncated smokestack in the vicinity of sheds 09 and 08 was complete in the early stages of the fire (figure 13) and was probably deliberately cut off to allow freedom of movement to the fire engine boom.

The clear existence of an effluent treatment area (Quonset hut 05) at the extreme east end of the plot strongly suggests that east is indeed the live bird arrival end. We believe Quonset hut 05 to have been the effluent treatment shed because of the dumping of effluent sludge from here into the neighbouring farm land. There is even a gap in the east side fence for this and there is evidence of such dumping in figure 33. The biggest shed (shed 10) appears to house the live bird arrival, hanging and coop washing department – the road passes right through it – which is how it should be. This being the case, the east end would certainly not contain any product despatch gates, nor purpose-constructed workers' exits, except possibly a canteen, the plausibility of which we examine in the next section. The east end would also need to have a rendering plant and boiler shed close at hand. Rendering is a process by which we convert poultry processing waste such as feathers, intestines, heads and blood into a protein supplement which is added back to poultry feed. Rendering uses steam for making the transformation.

3.2 Workers' Canteen

A canteen for so many workers (in excess of 300 at almost any hour of the day) ought to be a large structure connected to the main process shed with a covered passageway. It could be multi-storied and the path leading to it could also be useful as an emergency escape route, provided the interconnecting doors were left open or openable in the event of an emergency. If the first floor of such an external building were to serve as the canteen, its ground floor might serve as the central refrigeration plant (granted, neither safe nor recommended, but consistent with the general design philosophy adopted here). This argument is, therefore, purely rhetorical, as you will note soon.

Such a central refrigeration plant would require an area of between 700 and 1000 SqM. And a similar area would suffice for a decent dining space cum pantry cum scullery for a minimum of 300 persons at a time. But here is the irony – all three sheds on the east side (sheds 09, 10 and 14) which match this size criterion, are already candidates designated for other purposes through our work flow analysis. Furthermore, in a typical processing plant of this size the distribution of workers is approximately as shown in table 9. Of this lot only 135 workers (those listed in rows 1 and 4) could benefit from a canteen located at the east end. Why?

In a typical processing plant, the design of a common dining space/canteen is a complex exercise. It requires one to lay down the travel routes of workers from "clean" and "dirty" areas, separately from each other, from their separate work places via their individual rest rooms (men and women may share the same travel paths but not the rest rooms!) to the common dining area and back - two trips every shift. And in a typical process plant, the clean and dirty areas are located at different parts of the building and serious efforts are made to plan the layout so as to ensure that personnel can not wander at random from one to the other and mingle. Finally, remember it has been noted on the strength of overwhelming evidence that the workers' arrival and rest rooms are situated along the south end of the main shed, so it would be impossible to designate one of the sheds (09, 10 and 14) as a common dining space for all workers, given the need to route their paths to and from it via the south end rest rooms.

3.3 Work Flow

Poultry processing is divided into two broad areas – dirty area which includes arrival of live birds, hanging them manually onto shackles on an overhead conveyor line, killing by drawing a knife across the necks (manually or automatically, as hung birds pass on the overhead line), bleeding for a period of 120 seconds or more, followed by scalding in a hot water bath, defeathering, evisceration (removal of viscera or intestines etc) and water-bath chilling. Also from the viscera one must harvest heart, liver and gizzard within this area before sending the rest of it to be rendered. And plastic coops in which live birds arrive must be washed and put back onto the same trucks that brought them. All of this forms the dirty area.

After water bath chilling, carcasses move into the clean area where they are portioned, deboned, trimmed, weighed and then packed into consumer packs like sachets or trays. All of this comprises secondary processing. After this the product may be frozen by passing it through a blast-freezing chamber through a dwell time of four or more hours and then stacked in a frozen store at -18 to -20ºC. An alternative is to further chill poultry down to between -1 and +4ºC by placing crate-loads in chill stores and then load the crates onto trucks after adding ice into them, for retail sales. All of this forms the clean area.

Further, because movement of trolley-loads from secondary processing through blast freezing, to cartoning, to storage, or fresh chill storage, addition of ice and loading onto trucks, is another specialised job, we have a third broad work area – cold area. Women are preferred for secondary processing while men are better suited for logistics within cold areas.

Since this plant mostly sold fresh chilled products in local retail markets, we will assume that the bulk of the plant's output was packed in ice and despatched by trucks. For despatch of fresh chilled products there may

Table 9 Tally of workers in a semi-automatic plant of 12,000 BPH

Department and their daily deployment	**Persons deployed**	
	/shift	**In plant**
Live bird arrival, hanging, killing, evisceration per line of 4000 BPH, 3 lines, 35 persons with each line. (2 shifts of 9 hrs each/day)	105	210
Portioning, deboning, trimming, weighing, packing (3 shifts of 8 hours each/day, mostly women)	250	750
Supervision, security, maintenance/shift	20	100
Coop washing, offal handling, rendering, boiler, logistics, utilities & services, (2 shifts, 9 hrs each)	30	60
Blast freezing, chill, frozen stores, truck loading, (3 shifts, mostly men).	20	60
Total personnel required/day - 1st, 2nd shifts	**425**	**1180**
This is a reconstruction of staff employment at the plant based on reported totals and deductions made about the work flow analysis. An explanation of the arrangement of shifts as assumed above has been attempted in section 2.0		

have been several truck loading docks on the north side of the main shed. Besides this, frozen products were also produced and shipped and for this there was a despatch bay (D1 and shed 18) on the west side. According to one account, at the time of the fire the inventory of frozen poultry amounted to more than 3000 tonnes[20]. Like poultry processors in many other countries (India included), the owner of this plant probably used his blast freezing facility to stock up when live bird prices dipped. This would have required a fairly large frozen store. We have drawn a large one in figure 10.

Now we must determine the approximate number of personnel deployed for each major activity and mark the relative locations where they performed them. Poultry processing involves a lot of automation because humans are not able to function at the required line speeds. Over time, the industry has invented automation in a phased manner – starting with automating the difficult, hazardous and dirty functions, then automating the remainder where line speed remains the main challenge for manual work. Within the dirty area, most of the functions up to defeathering (excepting live bird hanging), were automated a long time ago. Automatic machines in this killing-defeathering department are therefore standard features, particularly in large capacity plants such as this one.

However, evisceration and water chilling do present a choice. If you wish to use a semi-automatic approach to evisceration, you must remain confined to line speeds of 4000 BPH or lower. Automatic evisceration machines are very expensive. Or in other words, you need to install three parallel semi-automatic primary processing lines to process 12000 BPH. Likewise if you wish to avoid high investment in water chilling of carcasses, you may use an ice slush chilling tank – like this plant did.

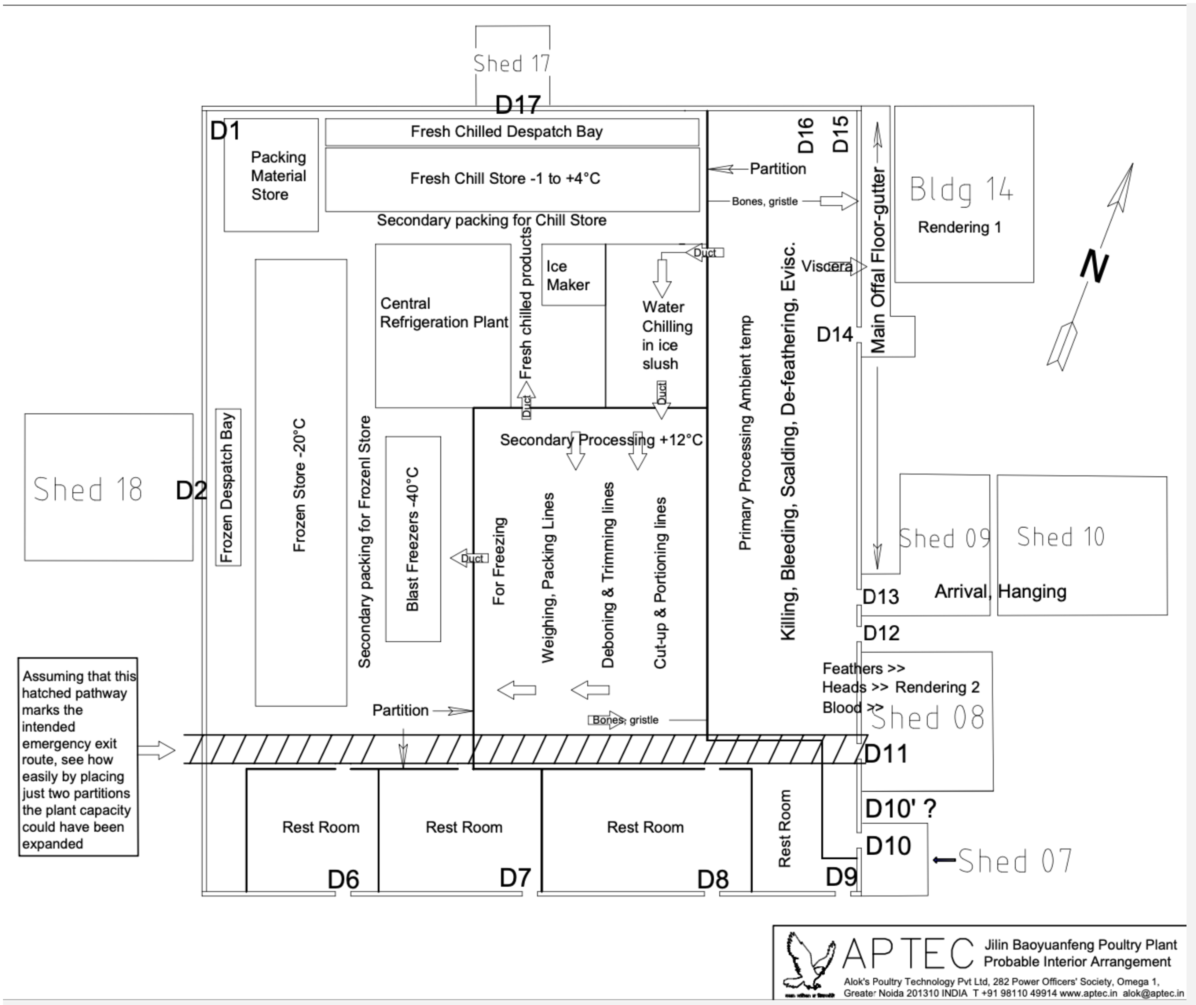


Figure 10 Reconstructed Layout Of Departments Inside The Main Shed

The owner of this plant appears excessively keen to minimise his investment, else he would not have opted for ice slush chilling (figure 30, where it is called pre-cooling pond). It is very rare to find an ice slush water tank in a 21st Century plant. Modern plants almost as a rule deploy a bank of screw chillers which chill carcasses from the initial 40ºC down to under 7ºC in a matter of 35 to 40 minutes. An ice slush water tank, on the other hand, takes very much longer. For a poultry processor it is useful to achieve water chilling in as short a time as possible because a long water chilling period effectively eats into useful shelf life of fresh chilled products.

Clearly investment considerations were paramount for this entrepreneur. Therefore, keeping with his character, we expect he would also have chosen three parallel killing and evisceration lines deploying semi-automatic evisceration machines to reach the capacity figure of 12000 BPH.

As regards choice of machinery in secondary processing, we see evidence of a labour intensive (yet reasonably appropriate) choice of Japanese cut-up machines followed by table-top manual deboning, trimming, weighing and packing. In figures 11 and 12 we see some remains of the arrangement of machines and workplaces in the secondary processing area. These pictures show the mangled remains of a semi-automatic cut-up line called the “Japanese Cut-up Line” or the “J-Shackle Line” within the industry. A central belt conveyor stands immediately below an overhead conveyor line and remains of supports for “T” track and ceiling from which the supports were suspended are visible in the foreground. Arranged along both sides of the belt conveyor are rows of work platforms called lady-lane trim tops where portion trimming, weighing and tray or pouch packing is done according to the required workflow.

Accordingly, in figure 10 within the secondary processing area we have shown three parallel processing routes (in the large rectangle. This area is typically held at +12ºC. Carcasses chilled in the ice slush tank would be fished out and portioned, deboned, trimmed, weighed and packed into consumer packs in this area. These operations are very labour intensive and consequently the largest labour force would be deployed here.

This department would need to be physically isolated from the dirty sections situated along the east wall. To trace workers’ access route to both clean and dirty areas we will have to follow the implicit intention of the plant designer to allocate the south side consisting of doors D06-D09 and D10 (the last appears to have been added as an afterthought) for the entry route of plant workers. So D6 & D7 would have been for blast freezer, frozen and fresh store logistics & secondary packing store staff (cold areas). One door would have been for men and the other for women. Immediately behind the doors would be the workers’ rest rooms and then the entry doors to their assigned work areas.

Similarly D8 & D9 would have been designated for men and women performing secondary processing. The state media alleges that 90% of the victims were female. Therefore D08 was meant for women and D09, which shows less area allocation, was meant for men. The spaces immediately after these doors contained toilets, locker rooms, punch card attendance recording machines, labour control offices and possibly dining tables where labour could have their meals. We return to the dining issue later. For the moment let us understand how, by the mere addition of two cross partition walls, the owner would have facilitated expansion of capacity at the cost of jeopardizing the safety feature of an emergency exit corridor initially inbuilt by the designer. This is explained in figure 10.

Figures 11, 12, 13 Left picture (11) shows trimming tables of a typical height of 800mm, arranged end to end. Middle picture (12) shows a J shackle line with the remains of a belt conveyor. Right picture (13) shows the presence of a second smokestack rising from somewhere in the vicinity of shed 08. The other smokestack rising from the vicinity of building 14 is also visible here.

Let us now move to the secondary processing area in figure 10. When chilled carcasses were fished out of the ice slush water tank and taken in, they could take three possible paths as shown in the diagram - with the work flow folding as required, to achieve the quantity of portioning, de-boning, weighing and primary packing operations as per that day’s production plans. At the end of this activity the product would be ready in its primary pack. It would then be placed in crates and sent into the chill store for subsequent despatch as fresh chilled products through the north delivery route, D17-shed17. Alternatively the primary packs would progress through a battery of blast-freezing chambers to secondary packing, term-storage in frozen stores and finally be despatched as frozen products through route D2-shed18 to markets. For use in each of these eventual despatches, packing material would be available from a store located right behind door D01. For secondary packing of frozen products this store would also hold empty cartons. It should be clear that receipt of chilled chicken and despatch of portions etc would have occurred through hatch doors marked “ducts” in figure 10. These ducts would have been designed for crates, and would not have allowed movement of secondary processing workers through them.

Since the news stories speak of fresh chilled supplies being the principal produce of this facility, the fresh chill store would occupy a large area at the north end, held typically at -1 to +4ºC and a despatch dock held at +8ºC. This entire section would be large enough for workers to assemble and move lorry-loads in line with the requisition indent of each downtown store. This dock would serve several lorries at once.

Could product despatch have occurred from the south end which holds D06 to D09? No, because internal roads leading to these four doors are not wide enough for trucks. They are sufficient only for workers. That these doors and their corresponding opposite ones at the other end of the rest rooms used to be locked after workers had entered at the commencement of a shift, is testified to by the absence of smoke tracings (see figure 26) on the south side wall. There is also a news story specifically mentioning that access doors to rest rooms were also routinely locked from the inside of the plant to discourage workers from making arbitrary visits to the toilet during the day[21].

Figures 14, 15 Figure 14 is a frame grab from a video shot in the evening of June 3, perhaps 13 or 14 hours after the fire started[22]. The orange glow in the background is not the setting sun, but a glow from flames over shed 17 or 18. While the main shed area immediately behind D02-Shed-18 was ablaze even 13-14 hours after the start of the fire, workers are seen rescuing packed chicken from what looks like somewhere in the middle of the north end.

If the origin of the fire was close to the central refrigeration plant where it has been shown in figure 31, why is some smoke issuing from the east end in figure 15? Note that this is a very early stage of the fire – the thick smoke cloud has not yet reached the upper border of the picture. In a poultry processing plant it is customary to have exhaust ducting drawing stale air from the clean areas towards the dirty areas and out. The dirty area in this case is in the east and clean areas are to the west of it, separated by a wall. There is a hot smoke column right over the west end and smoke from the east end termination of the ducting is seen hugging the roof to join the updraft created by the main smoke column.

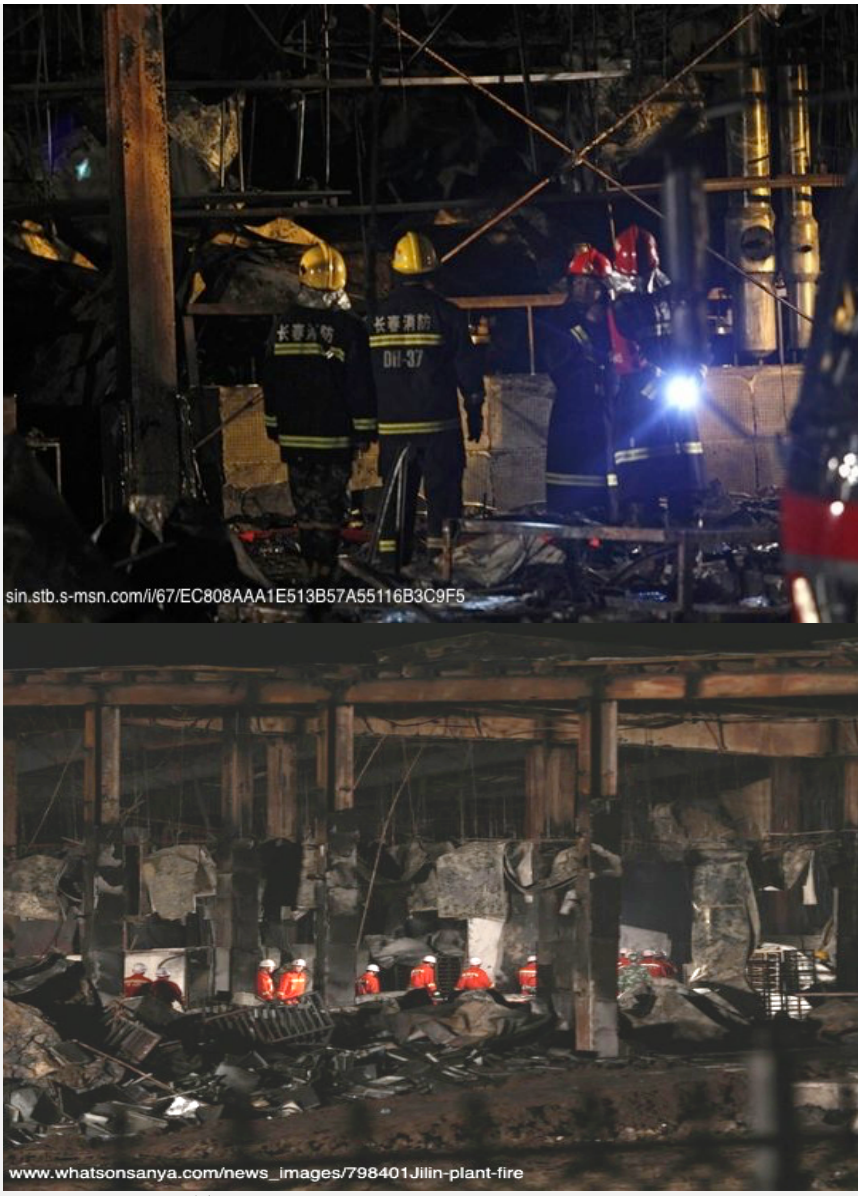
Does the slope of the main shed’s roof provide a hint about location of despatch bays? Yes. The north side holds the eves of the shed roof, therefore this edge of the building would be low and as such would not be the preferred end for an internal chamber that required a high ceiling. Fresh products are stored for short periods only – probably hours, before they are shipped out. So they are stored in short stacks of crates within low-ceiling chambers. On the other hand frozen products are stored typically for longer periods - weeks or fortnights, in tall steel racks within high-ceiling chambers. To locate high-ceiling chambers one would choose to be closer to the central ridge of the shed. And to locate a low height fresh chill store one would see no objection to being closer to the eves of the building roof.

Figures 16, 17 Note that this end has a high plinth and therefore these pictures have been shot at the east side. Figure 16 is the external door of shed 07. Note the eves end truss of the main shed towards its left. In figure 17 you see a close-up view of D16. Another view of it appears in figure 25.

Does the presence of a hydraulic pallet truck in figure 23 provide any clue? This hydraulic pallet truck was probably used to load cartons of frozen chicken into dispatch trucks. Packed cartons may conveniently be moved by hydraulic pallet trucks from frozen store shelves and loaded into trucks in this way. On the other hand, for loading crates of fresh chilled poultry packed with ice, you need a 1200mm high plinth against which trucks can be lined up.

These are the several reasons why we have assumed D2-Shed-18 as the likely route for frozen despatch and D17-Shed-17 as the likely route for fresh chilled despatch.

Figure 14 and 15 show carton-packed poultry being salvaged from the north end of the building. We have pointed out that fresh chilled products are typically packed with ice in plastic crates, not in master cartons made of corrugated cardboard. So the cartons we see being carted away through the northern exits contain frozen poultry drawn from frozen stores situated against the west wall of the plant in figure 14. Since the rescue is being done manually, it could have started early that morning considering that there were 3000 tonnes in stock. For this, the despatch doors on the north side would have been unlocked. If any of the cold area workers had not escaped, they could have escaped through doors opened for this purpose. The reconstruction in figure 10 accordingly shows no barriers to movement along the western interior of the shed.



Figures 18, 19. 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.

Could workers in the secondary processing area have also escaped through this fortuitous exit path? Possibly not - because (a) the smoke and absence of lighting would have prevented them from seeing where they were going or (b) there were no interconnecting paths between their area and the area used by secondary packing/cold area staff: the only possible passages were those marked "duct" in figure 10 and meant for passing crate loads of products through hatches in walls – not for movement of personnel. Some workers from the secondary processing area were reported in the ice slush chilling pool as they attempted to escape through the duct near it[23].

Even if humans could crawl through these ducts they would first have to locate them, which itself would not have been easy, given the presence of smoke and absence of lights. Eventually when they did reach the nearest ducts and wriggled through them, the despatch doors to the north might have been either shut or turned into a flaming barrier, so they might have had to negotiate a second duct leading them to the safer exit at the east end of the building. In other words first through the duct into the ice slush pool and then into the primary processing area through the duct feeding the ice slush pool.

3.4 Slope of Terrain and Number of Floors

The land slopes from the west towards the east and north-east. There is practically no plinth on the west side – the road being at the almost the same height as the plant floor. The central door leading into shed 18 in the foreground of figure 8 as well as the shuttered door D1 on the picture's extreme left both highlight this fact. This is also the case in figures 21 & 23 (the latter showing a pallet trucks at ground level within the burnt out interior of shed 18).

The plinth of the main shed is substantially higher than ground level at the east and north-east ends and has sets of steps leading in (figures 16, 17, 24 & 25). Since the bird arrival end should have a plinth of approximately 1200mm above ground level, one can say that the natural slope has been used advantageously in the design of this plant. Therefore we may conclude that the live bird receipt is done in the east. This is further corroborated to by the existence of the live bird gate in the east end of the compound (as distinct from the product despatch and workers' entry gate at the west end) and random dumping of some of the effluent sludge just outside a gap in the eastern compound wall (figure 33). There is a breach in the compound wall to facilitate the dumping of sludge in the adjoining field. This breach has been named 'sludge gate' in figure 7.

Figures 20, 21, 22 Top picture was taken from the main gate before the fire. It shows buntings and a motorcycle shed on the south end. The middle picture is from a BBC video[24]. It and the next two were shot at very early stages of the fire. The smoke is issuing from the west (despatch shed 18) end of the building in figure 20 where it appears to have originated[25]

The main process building has a plinth of approximately 16800 square metres (140m x 120m). It has a peak height of 13-15 metres (figure 7) and an average height at the north and south (eaves) 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 as per convention, which would create a plenum to carry utility pipelines and cables in the attic space. Many pictures show the delaminated false ceiling panels still dangling precariously at approximately this height.

On comparing this plant layout with standard layouts of similar capacity plants, we find that the given plinth area is more or less comparable except for the following four conditions: Provided (a) it is assumed that there was no internal second storey in the Jilin plant and that consequently the total floor area is taken as equal to the plinth area, (b) that the Jilin plant was meant only for the production of raw chicken products using a minimum of automation at a throughput of 12,000 birds per hour, (c) that the central refrigeration plant, which is required to be in a separate building, was in fact included within the main building and (d) that no common canteen area was set aside for the large number of workers employed at the Jilin plant.

The central ridge of this building is quite high, yet we see no signs (nor any need) for the designers to build and utilise an additional floor. Why? Probably, given the high precipitation levels at Jilin, and the possible snow load that could have been encountered there, the roof angle had to be steep, given the additional condition that everything had to be fitted into a single shed and therefore the shed had to be as much as 140 metres long. That the additional volume available within the shed because of the steep roof angle could have been utilised gainfully, but was not, can be blamed on the complications that this would have added to the structure and work flow. Yet the added volume could have been used to situate the central refrigeration plant within the building and thus achieve some degree of saving. But was the central refrigeration plant located inside the building as shown in figure 6? This question is discussed next.

3.5 Central Refrigeration Plant

In a large processing facility such as this, the use of a central refrigeration plant using ammonia is *de rigueur*[26]. When one relies on fluorocarbons, one can consider distributed compressor locations – but not with ammonia. It makes a lot of sense to build around a **bank** of low and high stage ammonia compressors, add some standby capacity and locate them within a central refrigeration utility building which you would expect to see close to the main shed. Considering the dimensions of the main shed, and the generally ubiquitous requirement of refrigeration throughout much of its extent, cost effective placement of the central refrigeration plant close to a north edge of the shed or on the lawn towards the west of it would have made sense. But we find no utility shed there. So we may conclude that the next cost effective, yet totally imprudent, location for it would of course be somewhere within the shed! Let us pursue this hypothesis.

A **If we assume that the central refrigeration plant was actually inside the shed. Where would you expect to find it?**

Where the internal height of the building was sufficiently large, say in excess of 10 metres and where one could construct roof monitors that would allow leaked ammonia to escape naturally. (No matter how good the valves and joints, some ammonia does leak and needs to escape. Looked at from outside, one would expect that the central refrigeration plant lay under the northern half of the central ridge on the roof of the main shed. The northern half has two ridges while the southern half of the shed roof has none. (See figures 7 and 33).

Very close to blast freezers, frozen stores, chill stores, ice maker and ice slush chilling water tank which together use more than 80% of the total refrigeration load in such plants.

Figure 23. The burnt-off roof of the frozen goods dispatch shed abutting the main process shed at the west end. Note the wrecked trolley.

B **Is there any direct evidence in support of our hypothesis?**

Figure 18 shows large aluminium sheet clad vessels and pipelines situated inside the building. Also, there are guy wires strung diagonally and appear to be holding some large structures upright. The presence of diagonally placed guy wires precludes the possibility of this area being in general use for poultry processing. We believe this is the central refrigeration plant.

C **Do we have any direct evidence in the published layouts (figures 30, 31) that the refrigeration plant was inside the process shed?**

No. One would not expect to find such a direct evidence in published diagrams. However we do find three rectangles in figure 30 that bear examination. The first, closest to the north end of the shed, is probably the chill store cum despatch bay for chilled products. The second rectangle, which has no writing on it, is probably the refrigeration plant. Please also see section 3.9 for more on this.

Figures 24, 25 Picture 24 (left) shows two firefighters standing in one of the lanes formed by two abutting sheds and structures to the east end of the main process building. This has been identified as a possible door between sheds 07 and 08 sheds. Note that shed 07 is intact while shed 08, which probably housed part of the rendering 2-boiler complex or the feather store, is gutted. The picture on the right (25) taken at the north side, shows some signs of fire and a collapsed roof-gutter. These form two possible emergency exits. The odd shaped door on the left was probably 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 maintenance area.[27]

D **Could one of the sheds/buildings directly to the east of the main shed contain the central refrigeration plant?**

Building 14 (figure 7) seems like a good candidate. It is certainly large enough and appears located along the original coordinates of the main shed so it was probably designed at the outset and is not an afterthought. But we have designated it as rendering plant number 1 because of the presence of a smokestack adjacent to it. This would be an ideal place to locate the rendering plant, right next to the end of the primary processing lines and separated from the main shed by a narrow main offal floor gutter (structure 13). Besides what purpose would a smokestack serve in a central refrigeration plant? It would make more sense to locate the central refrigeration plant across the fence directly to the north of the north-east end of the main shed.

Figure 26. This picture gives a good idea of the roof height at the eaves on the south end – some 7-8 metres. It also gives a good view of the prefab construction with fixed windows. Notice the vertical smear line left by escaping smoke. This line marks the joint between two adjacent prefab panels. The north wall comprises prefab panels alternating with sandwich panels, but the south end has only prefab sections.

For instance take structure 03. We cannot consider this to have been the central refrigeration plant because the aspect ratio (length/breadth) of this odd shaped building would require far more pipeline length than necessary. The location of structure 03 is counter-intuitive also, given the fact that most of the refrigeration muscle would be needed towards the north-west quadrant of the shed, which is too far away. Besides, if structure 03 was the central refrigeration plant, we would expect to see a gantry carrying pipelines from it over the internal road to the main shed. We do not find such a gantry in figure 33.

Taking all the above arguments into account, none of the sheds or structure on the east could have housed the central refrigeration plant. We are left with the conclusion that it was located inside the main shed.

3.5 Ventilation

There are no roof-mounted air extractors on the south half of the main shed roof in figure 33. The north half, having sustained more burn damage, clearly had two ridges to provide extraction of stale air from work spaces and allow entry of north-light into the attic. If one assumes that movement of air out of the building is not natural but directed entirely on forced basis (as it might well be, considering the massive size of the building), 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 8 shows none, nor does the Google map illustration in figure 33. 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.

The internal height within this building is enormous. Look at figure 19. The firemen in red appear to be no more than a fourth of the distance from floor to bottom of concrete beams. In this picture we do not see any signs of a false or drop ceiling having been present at 6 metres height as we would expect.

North of the central ridge the shed has two longitudinally running sets of roof monitors, possibly provided with glazing and vents (figure 33). That they do have vents is evident from the large amount of thick black smoke apparently issuing out of them in Figure 15.

Figures 27, 28. Picture for figure 27 was taken from the north end, close to gate 2. Shed 17 has been dismantled by this time. This and figure 28 (also showing the north wall, taken from closer to where shed 17 used to be), show that sandwich panel and precast RCC panels alternated for this entire wall for the length of the despatch bay (excepting the extreme north-east end shown in figures 14). We can conclude that sandwich panel sections housed truck-loading-dock-gates (which are easier to assemble along sandwich panel walls but not along precast panels). Quite clearly except where loading dock gates were actively aligned with trucks in the process of being loaded at the time of the fire, and the drivers could have been persuaded to back off, there were no escape routes on this side. Yet some of these docks had been opened on orders of the management to rescue packed chicken (see figure 13). Partially hidden by two soldiers in the foreground in figure 27 you can see structure 03.

3.6 Boiler & Rendering

We have established that the east end of the shed is the live bird entry or dirty end of the process. To locate boilers at this end, we scan the pictures for smokestacks. Smokestacks are associated with boilers and boilers in turn are used to raise steam. There are only two uses of steam in a poultry slaughterhouse. Roughly 80% or more of the steam is used for rendering or conversion of processing waste such as feathers, intestines, heads, blood and bones by hydrolysis into a protein meal for adding back to poultry feed. And the remaining steam is used for heating scalding water. After killing and bleeding, carcasses are passed through a scalder which holds water at roughly 58-60ºC to loosen the feathers and make de-feathering easy.

Look at figure 8, centre top area. You can see a smokestack rising just above the region of buildings 14 or 15. This is clearly where a boiler lies. Now look at figure 13 and you will see another smokestack close to shed 08. Because building 14 appears to have been built on the same grid as the main shed, at the absolute end of the dirty area, adjacent to structure 13 and has a floor area of approximately 1000 SqM (25x40m), we believe it housed a rendering plant.

A 1000 SqM plinth area is consistent with the traditional (and, sadly, grossly inefficient![28]) rendering plant layout designs that emerged during the first half of the previous century in USA, to cater to service rendering facilities of major cities there. So we can safely assume that building 14 is for rendering and consequently building 15 should house the boiler. In that case the steam line would first serve the rendering cooker and then proceed beyond the rendering building into the main shed for heating scalding water.

Now we need to explain the presence of the second chimney. What could have happened as the plant capacity grew rapidly. Our speculation about subsequent events follows our familiarity with the typical behaviour of other plant owners who have had to contend with rapid capacity expansion, starting from inappropriately designed processing facilities.

To cater to expansion, bird arrival, hanging, killing and bleeding areas would have been taken out of the main shed and re-established in sheds 09 and 10. Feathers would probably have piled up, awaiting rendering in a second rendering plant, set up, together with the boiler and smokestack, in that area. It is the smokestack of the second rendering set-up that we see in figure 13.

How would the processing offal have been divided between the two rendering plants? Feathers and heads from the killing operation would have been brought to shed 08 for rendering in line with the (underground) straight stretch of floor gutter marked as structure 13 in figure 7. Blood would have been piped directly into the cookers in the second rendering plant. Meanwhile soft offal (intestines) and bones would have been delivered to the old rendering plant and processed there. Bones from secondary processing cannot flow easily in a floor gutter. They are normally delivered by a conveyor belt or in trolley-loads into an offal pit from where, mingled with soft offal, they may be pumped up and raised for filtration and then gravity-fed into a rendering cooker. We believe that D14 is the door through which bones were manually dumped into the offal pit.

Why was a second boiler required? Since most of the steam is used in rendering, a boiler is always located near the rendering shed. Would it make sense to pipe steam from building 15 to shed 08, assuming that there was enough space in building 15 to install additional boiler(s) to cater to the new rendering plant? Probably not – you would lose too much energy from long exposed overhead steam pipes. We believe that with the increase in capacity the owner would have built a completely new rendering plant-boiler combination. Why is shed 09 odd shaped rather than rectangular? Clearly a part of it abutting the main process shed is the aisle carrying live bird track(s) into it. The rest of it probably houses the a boiler.

Why would JBPPP be so concerned with the generation of rendered meal, which is, after all, a secondary product for a poultry processor? Remember that the company owned a number of feed mills (see section 2.0) and would naturally have been keen to obtain inexpensive protein additives for it.

A word about rendered meal. You can render feathers, blood and soft offal separately to make feather meal, blood meal, offal meal or in their natural proportions to make mixed poultry meal. In each case the quaternary structure of living proteins contained in the raw material is broken down into its more fundamental building blocks - typically amino acids or peptides, which are their low molecular weight polymers. Upon rendering, the end products bear no physical or chemical resemblance with the original but retain the nutritional values. And the rendered meal retains the amino acids proportions of the original protein molecules[29].

There are some 20 amino acids and for proper nutrition of chicken it is best to provide them with mixed poultry meal which contains the natural proportion of amino acids of living chicken. However, since the hydrolysis of feathers requires different physical conditions than that of other raw materials, say soft offal; from the point of view of a feed miller, blending after separately rendering may be the preferred route. As we have noted, for the owner of the Jilin plant, who operated several feed mills, there may have been causes more complex than simple increase of rendering capacity at play.

Was the division of offal between the two rendering locations proportional to their capacities? Unlikely. Feathers occupy the largest volume of offal in a poultry processing plant. Since loading batch type rendering cookers is strictly controlled by volume, not weight, the second rendering plant would always have been overloaded while the first rendering plant would have remained underutilised. So in order to get the job done, the owner would have had to maintain a large pile of wet feathers close to the second rendering plant, perhaps in a large masonry well or pit, as part of the extended offal-floor-gutter structure 13. As production expanded, an endless race to deplete the pile of raw feathers would have ensued.

How would this race have panned out? The management would run extra rendering shifts at weekends and even make workers manually cart feathers from the pile or pit to the first rendering plant. But all along, the lowest part of the feather pile would remain there, within a masonry pit and entirely under anaerobic conditions. You cannot allow a feather pile to become much higher than a metre or so because a man flinging a crate-load of fresh feathers cannot do so to a higher pile. Therefore the masonry-lined pit would have been constructed with its lowest part deep under ground level.

And if all this was indeed true, this is where the case gets interesting. We return to this situation later, in section 5.2.

3.7 Waste Water Treatment

This facility was probably located in Quonset hut 05 and was probably of a chemical treatment type (as against the more efficient biological treatment type, which has remained the preferred type for several decades past). A biological treatment facility requires a heavier investment but pays off through lower operating cost and better efficiency. In contrast, a chemical wastewater treatment facility uses large quantities of common chemicals or minerals to neutralize the wastewater. It also generates corresponding large quantities of sludge which are difficult to dispose off except where local authorities are ready to turn a blind eye to dumps of sludge in adjacent fields. In this case these dumps show up clearly in the Google map (figure 33), adjacent to the feature marked “Sludge Gate” in figure 7.

3.8 Summary of Named External Doors

We have summarized all the named doors in Table 29. This is not an exhaustive listing of all external doors, but only represents those which are visible in the pictures included in this document and glimpses of doors shown in videos – but no longer visible because the walls have been stripped away during rescue operations. Where possible we have also commented about some doors listed here.

That brings us to windows. Buses and trains are required by law to have emergency exits. Some of their glass windows can be opened for passengers to escape in the event of emergencies. One can see in figures 8, 15, 20, 24, 26, 27 and 28, that this plant had a sufficient number of windows. Yet most of them remain intact through the incident, 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 8), which are too high for any escape attempt, and would not have been accessible anyway if door D2 was locked, 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 is evident from the photos, and hardly any of them is broken, nor do any have smoke traces.

What conclusions can we draw? Either the designers ignored the possibility of windows being suitable for use as emergency exits or that standard available emergency exit type windows were dimensionally incompatible with jigs and dies used in local manufacture of precast concrete exterior walls used in this plant.

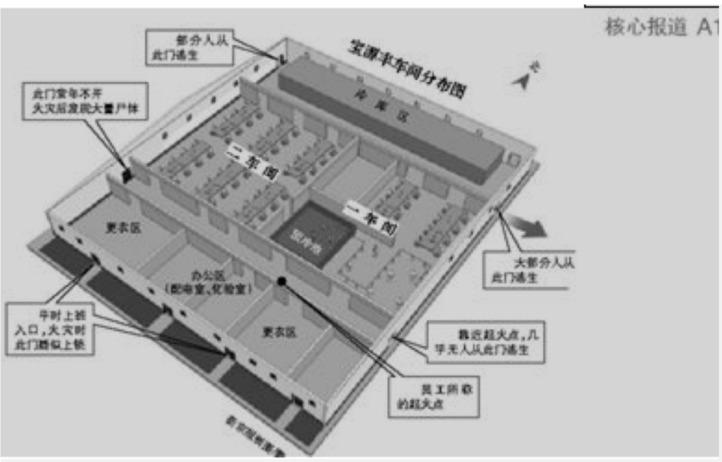
Table 29	Tally of External Doors In The Main Building (See figure 10 for position of doors)	
D1	**Normally locked.** Rolling shutter type door, probably meant for receipt of packing material and empty cartons.	West side
D2	This door is meant for despatch of frozen poultry products. It was **probably unlocked** and in use at the time of the incident as demonstrated by the presence of a hydraulic pallet truck in figure 23.	West side
D3 to D5	**Normally locked.** In two BBC videos we can see these doors were forced open to permit fire-fighting. Figure 8 (in which the entire sandwich panel wall on the west side has been ripped off) shows a view of the lawn. Since you do not see any traces of footpaths on this lawn either in figure 8 or in figure 33, it is clear that these doors were not in normal use and were probably permanently locked.	West side
D6 to D9	Figure 26 shows that the south side wall is made of prefabricated concrete with die-formed windows and possibly also door frames. Although these four doors on the south side are close to the motorcycle shed and are clearly designed to be the entry points for workers to different departments through designated doors, smoke streaks on these prefabricated panels shows that these **doors were** more or less **hermetically closed** after workers entered the shed.	South side
D10, D11 & D13	We assumed that sheds 7, 8, 9,10 and Quonset hut 11 had been built where they were because those locations needed additional floor space beyond the initial provisions and therefore these sheds had to be added later. To allow these shed spaces to be used, there must have been intervening doors joining them to the main plant, which we have labelled D10, D11 & D13. There may also have been a door between D10 and D11 but we are not certain of this. Shed 10 had interconnection with shed 09 and both connected to the main shed through that intervening door and then through D13. Also shed 10	East side

	communicated to the road because trucks carrying live chicken drove right into it. Therefore **primary processing workers would have easily escaped through one or more of these doors.**	
D12	We believe figure 24 is the same door. On the left of it is an intact shed & on the right a partially gutted shed with a high plinth – probably shed 09. We **cannot say if this door was locked or not.**	East side
D14	The structure we call main offal floor gutter runs along the east side of the building starting from the north-east end and with what appears to be a short interruption (not very clear in figure 33), runs into a pocket in shed 09 and possibly beyond. We believe this is a roofed external floor gutter aisle, the southern end of which holds a large stock of raw feathers and heads produced in the defeathering operation. The floor gutter aisle then continues northwards between the main shed and Building 14 which houses rendering plant 1 which receives viscera from primary processing and bones and gristle from secondary processing. The bulge in this aisle probably indicates the presence of an inspection spot and must therefore be connected to the main shed by door D14. We see no merit in keeping this door locked and **probably some workers escaped through it**	East side
D15, D16	For some inexplicable reason at least one odd shaped workers' entry door D15 was punched through on the north-east corner of the shed (figure 25) and another one (D16) which appears to have been part of the original design. There is one news report[30] which mentions that one of these doors was the entry point for the maintenance team and was **normally locked**. The key was in the possession of the maintenance head.	East side
D17	We have speculated that there were several doors on the north side for despatch of fresh chilled chicken. However, while an examination of figure 27 indicates the likely presence of several despatch docks, none of them are intact. Therefore we cannot be sure of the number of docks. **They were opened early in the event** and carton-loads of poultry continued to be manually rescued through this/these door(s) for the whole day.	North side

3.9 Alternative Interpretations of Layout

First we will compare the sketch in figure 30 with the conclusions and speculations arrived at by us. The sketch shows a long box-like structure on the north side (assuming that the arrow head with the single Chinese character indicates north) and several doors leading out from this side of the building. By our assumption this box-like structure is the fresh chill store. Shortly after the start of the fire, one or more of these doors had been opened to facilitate the rescue of cartons of chicken (figure 14). Next, we see an empty rectangle just below the chill store along the top edge. We believe that this is the central ammonia refrigeration plant. The third rectangle is in black with white Chinese characters across it. We cannot translate the text, but if translated, we wonder whether it could identify this rectangle as any feature of the processing plant that has not already been accounted for.

Next we will compare Caixin's sketch presented in figure 31. This English translation of the original was sent to Aptec by Dr Pearson and was used in this present version of the Jilin Baoyuanfeng story.



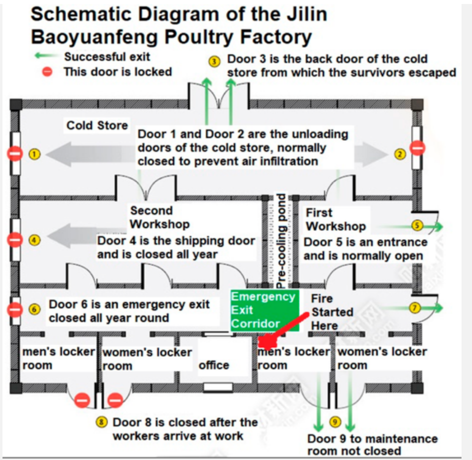


Figure 30, 31 Aptec is in possession of two layout diagrams of the internal arrangements of the main shed. The one on the left[31] showed up in 2013 around the time the original article had already been written. Not knowing the language, all we could say was that the arrangements bore some similarity with our own interpretation which has now been drawn and presented in figure 10. The picture on the right (figure 31) was sent to us by Dr Pearson in late 2022, bearing only Chinese text first and later, bearing a rough translation as shown. It was published by Caixin, a Chinese news agency.

We can see that there are many similarities (and some significant differences) between the findings of Aptec presented in this article and those in Caixin's sketch. These are explained in table 32.

Table 32	A Review And Re-interpretation Of Caixin's Diagram In Figure 30	
Caixin's Reference	**Caixin's explanation**	**Aptec's Interpretation**
Door 1, Door 2, Door 3	Doors 1 & 2 are shown as normally closed, located at the ends of the product despatch corridor	The product despatch corridor cannot extend all the way to the east and west walls. Aptec has shown that the west end contains a packing material store and the east end probably housed a maintenance area at the end of the primary processing section. Besides, the despatch bay would absolutely never communicate with the east end and its building 14 and structure 13. The last-named could have served no purpose whatsoever other than as an offal gutter. Both of these are considered the dirty end of the process and are never allowed to communicate with the cleanest end such as the despatch bay.
Door 4	Shipping door closed all year	Aptec calls it D2. It is the despatch door for frozen products. Presence of hydraulic pallet truck in figure 23 proves it could not have been closed all year-perhaps it was in use around the time of the fire. It was probably used several times a year whenever the accumulated stock of frozen poultry needed liquidation. Compare figure 21 and figure 8, in that order, and notice the group of workers standing in front of an external open gate of shed 18 at the early stage of the fire and later, at the end of the fire. You may arrive at the conclusion that workers escaped through D2, probably leaving the en-route interconnecting doors open, allowing the fire to follow them and completely gut the dispatch shed in the process. Door 4 was therefore not closed all year – it was opened when frozen products needed selling and the pathway could have been opened from inside at the time of the fire.
Door 5	Shown as first workshop door, normally open	Both interpretations appear correct, although its relative position in the sketch and the placement of pre-cooling pond are both disproportionate to the overall geometry of the plant and convey a distorted impression.
Door 6	Emergency exit door closed all year round	A video shot before the condition shown in figure 8 shows that there were three normally closed emergency exits, designated D3, D4 and D5 in figure 10, along this wall. This being the case, there were either three rooms to which they catered individually or to a corridor between the west wall and an extensive frozen store, serving both as an emergency exit corridor and access corridor for cold area workers. This is what Aptec has drawn in figure 10. Caixin's mention of just 1 door is an artistic simplification.
Emergency exit corridor between Door 6 and Door 7	Shown by Caixin as running clear from the west wall to the east wall	Interpretations about the doors' role and access are correct. But the existence of an emergency exit corridor running the full width of the building is not plausible as such a structure would completely destroy even the remotest attempt at segregation between clean and dirty area workers as interpreted and explained by Aptec. Such a corridor would allow workers from each area to mingle freely with each other at least four times every shift as they moved from outside to their work-places and back and from their work-places to toilets and lunch and back. A good plan would have placed glass doors meant to be smashed open in an emergency as partitions in this corridor. But as operated at the time of the fire, there absolutely HAD to have been walls separating primary and secondary work areas, else it is not possible to explain either the high death numbers or the disproportionately higher death percentage of women workers, which, Aptec maintains, worked in the secondary processing area. How this purported common emergency corridor could have been adapted for increasing the plant's capacity beyond its design limits is explained in figure 10.
Door 8	Reported as workers' entry door, closed after their arrival, drawn with an overdose of artistic liberty.	They are two doors, far apart from each other, as seen in figure 7, 30 & 33. They are workers' entry doors, closed after their arrival.
Door 9	Shown adjacent to each other, using an excess of artistic liberty. These are reported as being workers' entry maintenance doors. Left open.	They are two doors, far apart from each other, as seen in figures 7, 30 & 33. From the work flow analysis Aptec feels that the east side houses live bird arrival and primary processing. There can be no maintenance area at this end. Interpretation about door 7 is incorrect, as explained in figure 10 and two rows earlier in this table.
Location of the origin of fire	Men's locker inside Door 9, adjacent to an emergency corridor in the south-east quadrant of the main shed. The report of the State Council said that a short circuit that	Caixin's diagram presents a disproportionate representation of structures and uses a lot of artistic freedom. Perhaps the artist had never visited the plant and was unfamiliar with poultry processing.

	triggered explosions of ammonia pipes caused the incident	That the fire could have started where it is claimed to have, may be supported only under the hydrogen sulphide gas fireball hypothesis discussed in section 5.2. There is no role of ammonia pipes here.

To justify Caixin's diagram and to evaluate the following six arguments about it, one has to agree that we are looking at Caixin's diagram with its north side up. If this is not true, then, to support Caixin, almost every remark made by Aptec relative to work flow analysis in section 3.3 would demand falsification, and so would the Google map and most of the pictures broadcast by news agencies. Caixin's hypothesis about the origin of the fire would then have to produce a plausible counter to every inference drawn by Aptec in section 3.3.

Here are Aptec's arguments used in evaluating claims made by Caixin.

(a) There is absolutely no smoke damage of roof in this south-east quadrant of the main shed. Which of these two principles should Aptec be guided by - namely (a) that the minimum roof damage denotes maximum distance from the origin of the fire and the maximum roof damage denotes proximity with the origin of the fire, or (b) that roof damage is proportional to the length of time for which the fire raged there?

(b) One cannot imagine the presence of explosive or even combustible material in a men's locker room unless we subscribe to the hydrogen sulphide hypothesis (section 5.2). And considering the clear physical separation of the locker room from refrigerated workplaces, one should not even expect the presence of thermal insulation material such as sandwich panels in this area unless the architect made use of thermal insulation sandwich panels as a general purpose construction material! As section 4.3 shows, the architect of this plant was not unfamiliar with brick and prefab concrete panel walls, and brick-built dados. Therefore, insisting on the presence of sandwich panels in the men's locker room as the principal combustible material amounts to special pleading.

(c) One cannot assume presence of high amperage electrical circuits and controls in a men's locker room. Nor is there any evidence of the electrical sub-station's presence south of the main process shed, a pre-requisite for pleading possible passage of high amperage cables through this region.

(d) There are news reports that simultaneously with the explosions the entire plant's power went out. To suggest that a short circuit or fault in a low current locker room circuit could cause the entire plant's power to go out is highly implausible. This could have occurred only if most of the circuit breakers in the electrical system were of wrong specifications or setting. Once again a case of special pleading.

(e) Smoke and fire damage are in the diametrically opposite side of the building. An early picture shows smoke issuing from the north-west quadrant of the plant and from the east end through a possible plenum put in place for ventilation (figures 15, 20 & 21) or through the attic. Why would a fire that originated in the south-east quadrant move immediately to the quadrant located diametrically opposite to it? This could not have happened through any purpose-built ventilation ducting. Because to suggest such a ducting one would have to prove the need for drawing ambient air from the vicinity of a distant toilet zone to serve as an air intake for a refrigerated space! It would be equally implausible to suggest that stale refrigerated air needed to be exhausted through a distant toilet zone.

Figure 33 Google Map[32] chosen for reconstruction of the facility using Autocad

(f) One cannot explain the cause of fireball originating in men's locker room and spread of fire throughout in minutes without the special pleading that some explosively combustible gas had leaked and accumulated there. This gas could not have been ammonia as ammonia pipes had no business to pass through that area. The only gas that could have leaked and accumulated and been ignited into a fireball could have been hydrogen sulphide. More on this hypothesis in section 5.2.

4 Construction Features

4.1 Construction Materials - Sandwich Panels

Figure 7 shows some design details by stating the broad nature of external walls. Prefabricated RCC exterior walls with built-in windows (figures 26, 27 and 28), standard as well as ad-hoc doors (figures 16, 17, 24 and 25), sandwich panels above doors and windows, joining them to the roof eaves. Setting aside obvious administrative, and residential buildings, as many as 15 auxiliary structures required to be built, in many cases at odd alignments with respect to the main shed, and variations in doors and window styles, it would appear that the plant grew in capacity almost constantly and haphazardly through its five years of existence. Such a growth hypothesis matches the information given under section 2.1 about its capacity – real versus registered. Because different building styles occur at this facility, one must assume that a variety of construction materials were used. However the most common materials are steel sheet roofing over steel trusses and exterior and interior walls of sandwich panels, almost certainly of the PIR (see below) variety.

Sandwich panels come in many varieties with cores made of expanded or cross-linked polystyrene (EPS, EXPS), polyurethane (PUR and PIR), glass wool, mineral wool or rock fibre. As a thermal insulating free-standing material meant to make external and internal walls, the most common varieties are polyurethane sandwich panels. These are the truly combustible and hazardous materials in this facility, probably negligently installed in relation to electrical cabling and switchgear.

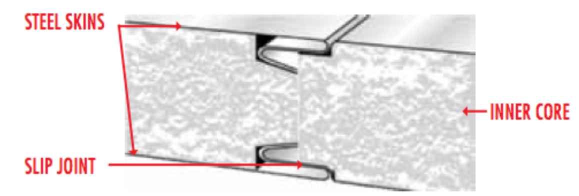


Figure 34. Diagram showing continuity of core material. **Source:** Insulated Panel Council Australia Limited. (IPCA), which commenced development of a voluntary code in 2008 to deliver a better performing panel and increase fire-fighting confidence.

There are two types of polyurethane sandwich panels in common use for thermal insulation. These are *polyurethane* type (PUR) and an 'improved variety', touted as possessing fire-retardant properties in foamed *polyisocyanurate* (PIR). **Both types burn** – the fire-retarding variety in turn produces vast quantities of dense black smoke (see figure 43) which causes asphyxiation and obscures exit signs in workplaces and corridors. Besides carbon particles, smoke from PIR and PUR fires contains hydrogen cyanide and its variants, oxides of nitrogen, and carbon monoxide, all of these being toxic. Also, more importantly, when these polymers burn in limited air, they produce *methyl isocyanate* gas – the same that caused widespread deaths of over 1500 people in Bhopal in 1984.

Fire in sandwich panels can spread at a speed of 0.5 metres per second! See the eyewitness comment in event 7 in Table 42. EPS and PIR are also combustible, but are not used in the form of sandwich panels – more common in creating thermal insulation layer under floors where they are safe from fire hazards. EPS is commonly known by its more popular brand name – Thermocole. It is available in un-clad blocks and sheets.

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. The fire retardant version of sandwich panel is filled with poly-iso-cyanurate impregnated with a fire retardant which "perversely tends to emit more and thicker smoke when they burn", says Prof J. Lygate[33], writing on June 11, 2013 about the incident.

The most common criticisms of sandwich panels in fires relate to the delamination of the outer skins exposing the core to the fire and its failure to stay in place instead of collapsing and the fire spreading within the panel. Electric cables, which are often placed over the false (drop) ceiling, come down with the collapsing panels and its snapped terminations may then cause short circuits. This is probably what happened at JBPPP, leading to outage of not just main power supply (which would have tripped the supply following a short circuit, anyway), but also the emergency power supply meant to energize alarms and emergency lighting. Or worse still, there may not have been any emergency power supply at all in the plant!

It is fairly established that sandwich panels will not start fires, nor will they be the first to combust. And combustion of such panels cannot create fireballs. They will burn when the panel delaminates and the core is exposed directly to the 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 34 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) 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 had 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.

As regards this plant, one report[34] says that plant owners in that area generally economise on sandwich panels. Ordinary panels cost 240 yuan per SqM, while fire retardant panels cost an extra 100 yuan per SqM. They purchase a small quantity of fire retardant panels to obtain approval, then they build the entire plant with the cheaper variety.

4.2 The Quonset Hut Design

Figures 7 shows 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 roof buildings. Of the last named, there are three - Quonset huts (see listing of structures along the left margin of figure 7). A Quonset hut is meant to be temporary, cheap and quick to erect and relocate, but it falls short of an ideal when used as an industrial shed. It is very difficult to establish any form of ventilation inside Quonset huts.

Figure 35 is a vintage picture of one such hut. *Notice the semi-circular top and absence of side walls, necessitating the construction of dormer windows for ventilation*. It is our belief that this kind of short-cut construction philosophy has influenced the design of several huts at JBPPP. Note for instance, the light steel reinforcements of the roof in the product dispatch hut in figure 23 where it has been burnt off, and the absence of doors (figure 8) except at the gable end.

Figure 35 Vintage picture of a Quonset hut[35] from the second World War. Note the self-supporting roof and door at the gable end. These huts were not designed for industry and afford very little ventilation possibility.

4.3 Wall & Beam

On the external surfaces of the main shed four different types of walls have been used. These are:

Sandwich panel walls (on the west and north). Look at figure 8. In the foreground you can see piles of sandwich panel steel linings which have been pulled off the western wall. Because these linings are only approximately 0.5mm thick, and because they have suffered fire damage, they are thoroughly crumpled. Why would an architect specify this material for the external wall? Probably because most of it was meant to retain the cold conditions in the frozen store. We have therefore drawn a rather large frozen store at this end in figure 10.

Look at figure 8 again. At the extreme left end, a short section of the wall and shutter gate remain intact. Clearly here the interior did not hold any material at sub-zero temperature. What could it possibly be? Packing material, of course. The ground immediately in front of this shutter shows some damage to the lawn which was caused by periodic arrival of delivery trucks, no doubt. Figure 14 probably shows another wall of this packing material store. Here the wall is made of **bricks**. Another evidence to assure us that the interior at this end did not need refrigeration.

Figures 24 and 25 show the east end of the north wall. Here the dado is made of masonry (probably a plastered brick wall), while the top is made of **sheet metal** – not sandwich panels. This fact is revealed by observing the edge of the odd shaped door. The sheet metal making up this door is thin, in fact thin enough to need bracings.

Finally look at figures 27 and 28 and read the accompanying write-up. The bulk of the north wall, excepting its ends, is made of **alternating prefab concrete wall sections and sandwich panel sections.**

Now let us move to the east wall. Figures 16 & 17 show details. Once again a plastered dado with sheet steel walls – given that the eastern interior needs no refrigeration, there would be no need to use sandwich panels here.

Next we examine the tie-beams and columns inside the shed. Figure 19 shows concrete columns and tie beams. Similarly you can see at least two concrete columns in figure 18. Since both these pictures appear to show the central refrigeration plant, one would not expect to find any false ceiling here. Does this indicate that RCC columns tie-beams and purlins were used throughout the plant instead of steel sections? No it does not. We expect that in the refrigeration plant RCC columns, and tie-beams would be preferred because they could form convenient supports for pipe-racks etc.

5 Probable Cause Of The Fire

Rows 1.2 & 3.3 of table 6 refer to an explosion followed by a fireball that engulfed the building in minutes. An explosion occurring on a summer morning as early as six would have been heard for miles around the plant and would therefore have been faithfully reported by witnesses whom correspondents contacted.

Rewriting the tale following exchanges with Dr Pearson, when we looked again at table 6, we marked three observations (rows 1.2, 1.5, 2.2) with asterisks. We also add that "according to Dr Pearson, for ammonia to catch fire it should be in a concentration of 1,60,000 ppm or 16%". This concentration is impossible to reach from normal leaks in pipelines, valves or vessels. Ammonia leaked in this way would then rapidly disperse and the concentration would rapidly fall well below ignition threshold. Besides, ammonia concentration of as little as 100 ppm smells so strongly that humans immediately notice it and repair the leak.

With the ammonia explosion hypothesis, which was almost universally proposed in the press, having been discounted we need to examine all reports again and in doing so we have stated the cause of the fire as briefly and as clearly as possible with the following **comprehensive statement.** We will use this **comprehensive statement** as our acid test in the rest of our review in table 36.

The fire occurred at a plant with jury-rigged, haphazard, ad-hoc, low budget expansion, beginning with three explosions, followed by a fireball at the start of a shift.	
Critical argument 1	**jury-rigged, haphazard, ad-hoc, low budget expansion** - we cannot take good housekeeping or good design as granted
Critical argument 2	**three explosions** - cannot be explained as a chance juxtaposition of three disparate events
Critical argument 3	**fireball** – absolutely requires the presence of an explosive gas
Critical argument 1	**start of a shift** - conditions had been building up before the shift and an action at the start of the shift probably triggered it

Table 36	Evaluating the Comprehensive Statement With Ground Realities
Electrical Spark	What causes a fire to start? You need an electrical spark. The spark may itself be strong enough to sound like an explosion. Or it may be small, even imperceptible, but can result in an explosion if it ignites a large enough accumulated store of highly combustible gas or vapour. It is impossible for electrical sparks of the magnitude of explosions to occur thrice in succession.
Explosively combustible accumulated gas	What gases normally present in a poultry processing plant can ignite explosively? A high concentration of ammonia gas can. However as stated above this is nearly impossible. We need to develop a hypothesis for another highly combustible gas and then test that hypothesis
Massive electrical spark damages ammonia pipe, causing release at explosive concentrations	Could ammonia pipelines or connections have been damaged following a large electrical short circuit and then the released ammonia got ignited? Yes. We have examined explosive electrical short circuits at 5 kiloamperes (figures 37 to 40). However, this could never have happened in the south-east quadrant of the shed as shown by Caixin in figure 31.
Small spark ignites accumulated explosively-combustible gas present in a series of interconnected chambers	Hydrogen sulphide is the only other gas that could exist, accumulate (in a series of occasionally interconnected subterranean chambers, with the interconnections themselves capable of being interrupted by flowing water in sewers/underground gutters) and explode into a fireball. The events that satisfy these conditions have been explained in section 5.2.

5.1 Reconstruction of Events - Explosive Electrical Spark Hypothesis

A sufficiently large electrical explosion, resulting from instant vaporization of a heavily overloaded part of a conductor or bus bar (or incorrect kind of makeshift "fuse") could have resulted in a flash fire if it occurred in close proximity to **exposed** polyurethane or even fire retardant polyisocyanurate (PIR) grade of insulating polymer – but probably not when these materials were in their native form, i.e. enclosed within a sandwich structure, protected between sheet steel.

Could the electrical short circuit itself have sounded like an explosion? To answer this, we compiled a series of illustrations from a YouTube video showing the blowing up of an electrical fuse rated at 5000 amperes. While our frame capture shows the essential features of the explosions, the reader would do well to watch the video and **hear the explosions** to better appreciate the point we are making.

In support of this hypothesis, we now propose that there was a heavy consumption of electricity, far exceeding the rated capacity of the components in the main control or distribution panel related to the refrigeration circuit. This is corroborated by the (a) rapid expansion of operating capacity as mentioned in section 3.1 and because of (b) the clearly demonstrated habit of the owners to go for ad-hoc solutions to immediate problems. Further let us not forget that (c) since it was the peak of summer, refrigeration load was expected to have been higher than usual.

Figure 37, 38, 39, 40 Top row shows cable terminations properly crimped to ensure good conduction. When terminations are improper or when they and the cables are required to carry much higher current than they are designed for, they heat up, oxidize, which in turn further worsens the heating effect and then they reach a temperature where the metal melts or vapourizes with the effect shown in figure 39. Here some metal has vapourized or exploded and a lot of the remainder has melted into glowing sparks. In figure 40 a 5000 ampere HRC fuse has ruptured with a similar overload, but resulted in a much weaker explosion. Note the grey vapour around the fuse. It is vapourized metal. **When you watch the video[36] you can experience the true magnitude of the explosions** accompanying each event.

We additionally hypothesize that this control or distribution panel was located inside the building. Since the plant had expanded very rapidly, the conductors were being made to carry much more current than they were initially designed for. The electrical cables and bus bars were constantly running hot. Both of these are made of aluminium. When aluminium runs hot its surface oxide layer builds up and makes increasingly poorer electrical contact. This sets in place a positive feedback loop and sooner or later a large portion of the conductors at the termination points heat to the point of melting and then the molten metal evaporates into a metallic cloud in the form of an explosion. One large explosion may physically disturb adjacent terminations sufficiently to cause sympathetic explosions in other circuits – but once this is stretching things a bit! And you need to form your own opinion whether the 5 kiloampere explosion is loud enough to have been heard outside the shed.

Is this hypothesis supported by observations?

(a) Since the main despatch point was from shed 18 (see figure 7) it follows that this end of the building housed the frozen store, chill store and blast freezers and it would be prudent and economical to house the central refrigeration plant nearby. See figure 18 which shows guy wires and thermally insulated and aluminium clad vessel and pipelines. The presence of guy wires indicates that this was not a regular work space and the presence of large insulated vessels suggests that the main refrigeration plant was located here.

(b) If the fire started here, smoke would have first issued from the monitors at the shed 18 end rather than the cluster of maintenance sheds and structures at the opposite end of the building (sheds/Quonset huts and structures 11, 12, 13 & 14). We have evidence of this in figure 21. Note that shed 18 is reasonably intact at this stage, in contrast to its appearance in figure 23 where it is entirely burnt up. This picture was taken at an early stage of the fire and the smoke is seen coming out of the origin of the conflagration. Even figure 22 shows that the smoke is generally issuing from the west end of the building. Therefore the origin of the fire cannot have been where Caixin proposes.

(c) Row 1.5 in table 6 mentions three explosions. If we assign a short circuit or sudden failure of an electrical termination as the cause of the first explosion, then we must accept that the second and third explosions were consequential to the first explosion and did not signify independent events.

If we adopt Caixin's hypothesis, we cannot account for a second and third explosion save by assuming that the only available combustible material (being urethane foam) caught fire *explosively*. This sounds ridiculous - people ought to have heard explosions right through the day because the conflagration was mostly urethane foam and ammonia burning!

The point of origin of fire suggested by Caixin has no ammonia piping. So if we must explain the subsequent two explosions on account of any other combustible material besides polyurethane we will have to resort to special pleading and conjure up a couple of canisters of combustible material like gasoline into the vicinity of the men's locker room!

On the other hand, the explosive electrical spark ground zero is right in the heart of ammonia piping area. The electrical explosion could have damaged any number of ammonia pipelines in the vicinity and it could have caused the second and third explosions.

(d) When you examine the context for which the retrofit gadget described in figure 45 was invented by Aptec, you will appreciate how an electrical short circuit could have started the fire but could not have caused an explosion. Such a short circuit could have occurred between an electrical cable and the steel cladding of a sandwich panel and consequently a bit of the cable and also that of the panel cladding would have explosively evaporated. But the quantities involved would be rather small and this explosion could not have been heard universally by people located outside the plant.

Summing up, here are the hypotheses.

The fire started as deduced by Caixin, in a locker room close to the east end of the building, which had no combustible material, let alone any explosively combustible material. At the start of the fire thick black smoke issued from the **opposite end** of the building – there were no signs of a fire at the east end. Judging from the picture in figure 8, which was taken when the fire had been completely extinguished, northern and western parts of the roof show fire damage. There is no damage whatsoever at the east end roof.

5.2 Reconstruction of Events – Combustible Gas Hypothesis

(a) When the initial plans of the processing plant were drawn, probably for 6000 BPH, with the possibility to expand to 12000 BPH, the workers' rest room area was drawn as in figure 10. Because the land sloped from west to east, all the sewer lines were built underground to lead to a common cesspit area somewhere at the eastern extremity of the plot of land.

(b) Although the initial plans were for a reasonably high level of automation in evisceration, the owner chose the cheaper investment path available through low technology, manpower-intensive options and built his plant with three parallel primary processing lines, using the least level of automation in evisceration. But in doing so he ran out of space and had to construct a number of ad-hoc sheds. Meanwhile he also wanted to benefit from the boom for processed poultry. So he ran the plant round the clock. All of this placed further pressure on space - particularly in rendering of feathers.

(c) To solve this problem he built a second rendering plant in limited space and of insufficient capacity – probably shed 08. This led to an ever-increasing stockpile of raw feathers. To store this pile in anticipation of running extra shifts on weekends and possibly by additions to rendering capacity sometime in the future, he built a large masonry tank close to an extension of the main offal gutter shown as structure 13, possibly leading up to shed 08. This tank had necessarily to be large and deep because feathers do not compact easily and you cannot heap crate-loads of feathers over a pile higher than a metre or so.

Such a pile of feathers develops anaerobic conditions at the bottom, almost as a rule and this never got emptied or cleaned up because the feather pile kept increasing, thus preventing anyone from reaching the bottom.

So over time the bottom of this tank corroded through the destruction of cement in the masonry by the anaerobic respiration of *Thiobacillus concretivorus* and this ultimately led to joining of the feather pit with the sewage main. Some feather clumps obstructed normal flow within the sewage main and later the sewage main itself became an extended anaerobic culture medium.

(d) Hydrogen sulphide gas continued to be generated and accumulated above liquid sewage levels in pockets formed by goosenecks, level differences in pipe sections, corrosion of masonry structures and branch connections within the sewage main. This gas could now be released in steps through inlets into the mains when water ran into it and disturbed the liquid-gas interface levels.

(e) Exactly such a disturbance occurred on the morning of June 3, 2013. Men walked into their rest room and ran water taps and operated toilet flushes. The liquid-gas interface inside the sewer mains got disturbed and entrapped gas gushed out in three huge burps. This volume of gas needed not a major electrical spark but just some loose, intermittently sparking cable connections, to ignite. Even the toggling of a light switch could ignite it. Moreover, judging from the quality of maintenance at the plant, one cannot rule out the existence of loose electrical connections in low current circuits throughout the facility.

(f) Hydrogen sulphide gas is heavier than air. It had been issuing from the sewer main into the locker room in fits and starts and may have accumulated before the start of the shift, and the first burp would have increased the quantity available. The first explosion created a pressure wave that caused the underground liquid-gas volumes to oscillate. Each oscillation burped more gas into the locker room and created the next two explosions.

Insert 41 How Anaerobic Digestion Works

When feathers are piled up, the external surface of the pile dries up while the internal mass remains wet and presents an anaerobic environment. It is then that a ubiquitous facultative bacterium called *Thiobacillus concretivorus* gets active. Under anaerobic conditions it uses sulphate in dust or masonry containing cement as its oxidant instead of oxygen from the air. It then emits hydrogen sulphide gas instead of carbon dioxide as the end-product. Hydrogen sulphide is highly combustible. When this gas is confined, as in gutters and sewers where anaerobic conditions are the rule rather than the exception, there are possibilities of flash fire, flash-back or fireballs – all of which would be different expressions to designate an explosion if a spark occurs in the vicinity of any explosively combustible gas.

Interestingly this microbe cannot extract sulphur from burnt clay brick structures - it has failed to do so from the 2000 year old burnt brick lined *cloaca maxima* in Rome. Because this microbe was first identified, studied and named as late as 1945, it remains a scientific curiosity and has never been recognized as public enemy number one of civil engineers.

At low concentrations humans can smell hydrogen sulphide gas as a strong presence of rotten eggs, but as the concentration rises, humans can no longer smell it because of a process called *olfactory fatigue*[37].

If you are unconvinced of the extent of structural damage that anaerobic digestion can cause to public sewers lined with masonry, you need to examine them along city roads in crowded areas.

Floating styrofoam creates a virtual seal precluding the entry of air into the sluggishly flowing mass and huge chunks of the retaining side walls of the gutter keep peeling off and falling in. This is because cement is destroyed by *Thiobacillus concretivorus*[38]

Every Indian city features miles and miles of such open municipal drains showing such side wall corrosion. And the city authorities keep spending billions every year in replacing the masonry walls instead of creating aerobic conditions in the flowing mass.

Is all of this plausible? Has hydrogen sulphide gas actually been generated by this bacterium from a pile of accumulated chicken feathers before? Yes, it has. In the early 1960's a worker at a poultry feather processing plant died after being exposed to hydrogen sulphide gas for an estimated 15.20 min (Breysse, 1961). More recently, Tyson Foods, USA, was awarded a fine of half a million dollars for the death of a worker through exposure to hydrogen sulphide gas in a feather rendering plant[39]

(g) These explosions crated a fireball which shot the false ceiling of the workers locker rooms upwards. Fire sped through the attic space and knocked out electrical systems because all the heavy LT cables ran over the false ceiling. With the destruction of this support, LT cables plummeted downwards, shearing all termination points, possibly causing short circuits in the process. After this the power went out and fire, now spread throughout the attic.

(h) There was no more combustible material in the southern half of the shed, but there was plenty in the form of thick thermal insulating panels and carton packed poultry in the northern half of the shed. So the fire damage to the southern roof was negligible but the damage to the northern roof was extensive (figure 8).

(i) When the fire was well established in the frozen store, it caused leakage of ammonia in the adjacent central refrigeration plant and that added more fuel to the flames. Conscious of the leakage of ammonia, the authorities ordered evacuation of nearby residents.

(j) The owners continued rescue of carton-loads of poultry from the vicinity of the frozen stores well into the night (figure 14). Meanwhile correspondents from different news agencies heard that both ammonia and sandwich panel were flammable and so their reportage included this chant and they built their stories around this chant. Not aware of the required high concentration of ammonia to make it combust, we at Aptec likewise added to this chant in our report of 2013.

(k) Level of fire damage does not only indicate the spots where the fire raged longest, but also the escape routes which fleeing workers took. So fire damage is extensive in shed 18 and almost non-existent in the south end. Doors on the east show the routes that fleeing workers took.

6 A Case Study For Designers

Putting aside possible 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. So instead of jotting down a laundry list of do's and don'ts, we felt that the retelling of this story would itself clearly tell the planner what he should do and what he should avoid.

As designers and planners of poultry processing facilities, what also concerns us here is a better understanding of local cultural habits that can render even the best and safest machine and plant design futile. This case study should be 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.

To sum up,

(a) Technology and culture must be in synchrony. Culture is a slow-moving, lumbering milieu. Where technology remains out of sync or falls short of being fully absorbed, culture simply short-circuits it and lands the customer with the worst of both worlds.

(b) The smart industrial 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.

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

(d) For the markets it operates in and hopes to build a durable presence in, the smart management is aware of all this. After all, it knows that globalization also means a world where even a stepladder that does not carry a legally valid and convincing caveat against incorrect use, can land it into costly litigations.

7 Slaughterhouses - Construction Methods & Proneness to Fire Hazards

This section was included in this chapter following news of a conflagration that occurred at the under-construction plant of Swami Feeds at Dharapuram in Tamil Nadu in July 2021. The plant was being constructed to the designs supplied by Marel of Iceland. Most people in the poultry processing industry heard of this event but there is no reference to it on the internet. On talking to the owners, this author learnt that the fire occurred when the machinery had not yet been put into operation. There was only a small lighting load on the cables. Yet the fire occurred and took down the entire sandwich panel structure.

Sandwich panels were invented for thermal insulation and their use should be limited to that purpose. In recommending construction poultry slaughterhouses in two parts – from arrival to screw chilling in brick masonry with RCC roof and the subsequent portioning, de-boning, packing, blast freezing and cold storage areas with sandwich panels and truss roof with drop ceiling (in other chapters on the subject of design in this handbook), Aptec has perhaps echoed the sentiments of IFBS Galileo[40] who wrote

> "In recent years, insurers in Europe, for example in the United Kingdom, have increasingly been confronted by major damage due to fires where sandwich panels were evidently involved in the construction. As a result, these light buildings have come in for increased scrutiny from insurers."

Table 42 Some Recent Conflagrations in the Processed Food Industry

	Event	Probable/reported Cause
1	3 June, 2013 at Jilin Baoyuanfeng poultry processing plant in Dehui, Jilin province, China. Facility completely gutted, 121 dead. (Aptec posted a detailed report entitled **What Happened At Jilin Baoyuanfeng** on this in August 2013). This chapter is a retelling of the same event	Experts identified electrical sparking near a toilet as probable cause as it lit up the sandwich panel construction.
2	27 June, 2013 Imperial Food Products chicken processing plant at Hamlet, USA. The fire resulted in the death of 25 people and 56 injuries.	Hydraulic oil leaks into an oven, fire spreads to sandwich panels & embedded gas pipes.
3	14 June, 2015 the Tyson plant at Farmington Hills Ice Arena plant in Michigan, USA. Facility gutted. Workers evacuated to safety.	Power surge caused ammonia leak at relief valve
4	17 June, 2015 at Frigorio Allana in Ghaziabad, India. Packing buffalo meat. Facility gutted. 5 injured but survived.	Suspected ammonia leak, in association with sandwich panels
5	17 June, 2015 at Koch Food Plant at Montgomery, USA. Facility gutted. Workers evacuated to safety	Ammonia leak
6	15 March, 2017 at Katiyar Cold Storage for potato in Shivrajnagar, Kanpur, India. Facility gutted. 5 dead.	Ammonia leak, in association with sandwich panels
7	17 November, 2017 at Longyuan Food Co's carrot packaging plant in Shouguang City, China. Facility gutted. 18 killed, 13 injured, 3 missing. There were many evacuation routes but none visible in the dark. "**The fire engulfed 100 metres of workshop in less than a minute**", Liu Fangping, a migrant worker from northwest China's Gansu Province told Industryweek.	Ammonia leak, in association with flame retardant sandwich panels
8	28 January, 2021 at Foundation Food Group poultry plant, Georgia USA. The plant uses liquid nitrogen as a cryo-refrigerant. Facility gutted. Killed 6 and injured 12 before the premises were evacuated.	Nitrogen leakage displaced air and caused asphyxiation.
9	21 March, 2021 at South Pacific Meats in Awarua, Invercargill a Southland meat processing plant, New Zealand. There was full evacuation of personnel and no injuries were reported.	Ammonia leak possibly following a power cut - may have caused sparking.
10	Week 2 of July 2021, Swamy Feeds poultry processing plant under construction at Dharapuram, Tamil Nadu, India. Sandwich panel construction designed for the entire plant gutted. No lives lost as the plant was not in operation and there were no operating staff present.	Electrical cabling negligently pulled through holes drilled in sandwich panel short circuited & so ignited the panels

Sources[41]

Do fires occur in poultry processing plants (which apparently contain nothing combustible and are often too wet to light up)? Yes, they do. We need to first accept this fact. To help you to do so, we have compiled an indicative list of fires in poultry and meat processing and other similar food processing establishments where sandwich panels and ammonia gas refrigerant coexist.

Figure 43 Dense Black Smoke at Chinese Carrot Plant Fire *Source:* www.dailyexcelsior.com/18-killed-fire-accident-chinas-food-factory, 2 December, 2014

There may be three or more participants to fires in such premises. **First** there is ammonia gas. Ammonia gas often leaks from joints in valves and flanges, but since it is lighter than air, it tends to accumulate near the ceiling and does not by itself reach a sufficient concentration to be the primary fuel. Besides since it has a strong, distinct smell at just 100 ppm, people can detect a leak and take corrective action readily. However once a fire is started, say, from an electrical event, sandwich panels, which are **second** in the list of combustible materials, can ignite and subsequently refrigeration pipelines exposed to high temperatures may leak large quantities of the gas and accelerate the conflagration. **Third** there may be packing material consisting of plastic, paper or wood in the workplace. And **finally** there may be a gas or liquid fuel pipeline passing close to the sandwich panel structure.

Ammonia is by far the most important refrigerant today. Hydro-fluoro-carbons are no match for it, specially in heavy industrial applications. But by the use of appropriate system design we can reduce all hazards related to it. In fact, as part of the new green energy initiative, bulk maritime transport of ammonia is considered a viable strategy[42] for transport of hydrogen as a fuel. This is because hydrogen itself requires enormous pressure to compress into easily transportable tanks whereas ammonia compresses readily and as a chemical component of ammonia molecule, cost-effective transportation of hydrogen then becomes a lot easier. So we need to learn to live with ammonia and master all safety protocols related to it.

7.1 Historic Plant Fires That Led To New Standards

In table 44 we lay down a selection of procedures that ought to be followed in sandwich panel constructions. They have been culled from the efforts of Tyson[43], who experienced a number of fires at their meat plants, diligently learnt from the experience and shared their findings; the work of US fire department; emergency response teams; safety management experts; and finally an inspection and analysis of the Hamlet[44] fire in the Loss Prevention Bulletin of 2018 summarizing the events in a copyrighted article by the Institution of Chemical Engineers.

Our procedures also take into account observations of Galileo Kreatives[45] and US Alliance for the polyurethane industry[46]. Here is an account of some of these fires. Those who wish to examine the contrast between the two plants may refer the US Fire Administration Report on the subject[47]

Table 44 A Compilation of Important Rules to Follow With Sandwich Panels And Ammonia Refrigeration

1 Planning Stage		
1.1	Planning adequate and sensible exits. [Exit routes are divided into (a) exit access, (b) exit (route) and (c) exit discharge].	Exit access and exit discharge shall not be lockable from either inside or outside.
		Access to emergency exits shall consist of easily shatter-able glass pane, and for shattering the same a hammer shall be conveniently placed near the door.
		Exit routes consisting of corridors leading to exit discharge shall be a minimum 720mm wide & 2300mm high and shall not be obstructed by stored material.
		Every product dispatch bay shall have a shatter-able glass emergency exit door.
		Exit signs shall be in local language(s) + English + pictogram on exit access.
		Exit signs shall be lit by a self-contained, locally placed power supply, so that outage of power lines do not cause the sign to blank out.
		Exit signs shall be at both the top of the door and the bottom. With the use of PIR panels, billowing black smoke hangs close to the ceiling and obscures signs close to the ceiling. See figure 43.
		Every workplace or room shall have two exits, preferably placed at opposite ends of the workplace or room. Doors shall be side hinged and swinging out.
1.2	Planning fire blocks	Fire blocks may also be required in the design of certain concealed spaces, and at penetrations into pipe chases and ventilation shafts.

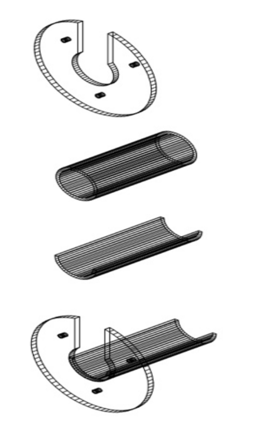
1.3	Planning thermal barriers for RTE areas	Polyurethane should not be used in areas immediately adjacent to or above combustion equipment (such as furnaces and chimneys), high temperature process equipment or piping. If thermal insulation is required, it shall be of rockwool.
		Where open flame cooking is to be done, such as in commercial fryers, ovens, woks etc, the space shall be separated from urethane foam structures by a masonry wall/thermal barrier that can contain flames for a period of 2 hours.
2 Installation or Construction Stage		
2.1	Safety during storage and construction	Foam board-stock shall be stored at construction site in limited quantities, in divided lots, in accessible locations, free from ignition hazards, with fire alarm & water spraying system.
		There shall be no welding or metal cutting in contact with these stored foams.
2.2	Working with foamed-on-site foams	PUR or PIR foamed-on-site foams may be used to fill cavities within masonry walls or under grade-level concrete floors. Such foamed-on-site polyurethane chemicals shall be mixed and applied only by applicators trained in their proper use and familiar with their limitations.
3 Interaction With Other Systems for Safety		
3.1	Refrigeration piping fixture	Within the workspace all pipes/fixtures carrying ammonia shall be of welded construction only. Any fixtures requiring bolted-together flanges shall not be installed inside the workspace.
3.2	Ammonia sniffers	Are required in all work areas where ammonia is likely to spread in the event of leaks. Cabling between such sniffers, controls and alarm devices shall not be laid over false/drop ceilings, but suspended from trusses, well above false/drop ceilings.
3.3	Open flame in cooking equipment	Sections housing such equipment shall be housed only within masonry enclosures or rooms (thermal barrier). The masonry enclosure shall be able to withstand and contain a fire for at least 2 hours, not letting it spread out of the enclosure.
3.4	Sandwich panel false ceilings, drop ceilings, roofs	Shall not support electrical power or signal cables directly because when so supported, in the event of a fire, these cables burn rapidly and cease to function. Since these cables may be part of the fire safety installations such as emergency lighting, alarm system, fire and smoke sensors, emergency exit signs on doors, etc, they will fail in the event of a fire and not be able to perform the function they were intended to. If cables are required to traverse above a sandwich panel roof or drop ceiling, they may be supported clear off it, from trusses that form the support for steel sheet roof.
3.5	Thermal Barriers	Building codes may require foam insulation to be separated from the interior of a building by an approved thermal barrier such as 13mm gypsum wallboard (drywall). (Except some PUR/PIR panels that have earned approval without thermal barriers through fire tests such as ANSI/UL 1256, FM 4450, UBC Standard 26-3, FM 4880 and DIN 4102-2).
		Where thermal barrier conditions prevail, thermal barriers are required both above and below the panel for suspended ceilings. This makes them unsuitable for wet processing plant areas because kraft paper liners on gypsum boards attract fungal infestation in humid or wet conditions of slaughterhouses and should not be used.
3.6	Sprinklers	In many cases, type of occupancy and type of construction also may require the addition of sprinkler protection and/or smoke detectors. Sprinklers are required except in wet areas. Walk-in coolers or freezers of less than 400-square-foot (37.16 SqM) area are considered fixtures and do not require sprinklers.
4 Orientation and Training of Personnel		
	Training, Drills	All personnel to be trained about emergency response, and periodic fire and disaster response drills done to orient them.

7.2 Retrofitting Threaded-through Nipples for Cables Through Sandwich Panels

Because a large number of PUR/PIR constructions exist in the broiler and meat industry today, many of which may have been constructed without complying with proper standards, we believe they need to make corrections where ever possible. Here we present a retrofit device to correct one of the most important defects in existing sandwich panel constructions.

When lay fabricators work with PUR and PIR sandwich panels, they often fail to observe essential safety standards. For instance, ever so often such constructions require one to pass electrical cables through panels. The sloppy approach is to drill a hole and pull the cables through the hole thus drilled. This is dangerous. When you drill through panels, the steel cladding develops sharp edges and retains drilling swarf. As you pull cables through, the electrical insulation gets stripped off. If this does not cause an immediate short circuit, then it will do so later, with vibration and small movements. The short circuit may be between live wire and sandwich panel cladding or between conductors. It really does not matter because the spark may then set alight the insulating polymer.

So if you are about to begin construction, run wires through SS pipes placed in the holes you drill through panels. If you have already built without exercising this precaution, use this retrofit to isolate the cables from the polymer. When you do that, if an electrical short circuit does happen because of damaged insulation of your cables, the spark will remain confined between the SS half cylinders and the short circuit will trip the circuit breaker rather than cause a fire. Of course, you must earth the panels themselves.



	Prepare a pair of disks from 2 mm SS sheet. Outer diameter 75mm, inner 25mm. to suit such a cable hole through a 60 mm thick panel. (Of course, you will alter dimension as required for the cable hole diameter and panel width). Three small holes are for self-tapping screws. Cut a length of SS tubing of 128mm length+1 saw width, OD 25mm.
	Split the tube lengthwise (adjusting for saw width to make a tight fit for the hole) to get a semi-cylinder of that length, with finished, de-swarfed height of 12.5mm. Then cut it into 2 lengths of 64mm each. Owing to the width of the saw blade, you will get only one good pair of semi-cylinders per pipe length.
	Weld each semi-cylinder to the disc as shown. Clean surfaces and file down edges and swarf. Now you have made the fire safety nipple. Push a pair of nipples into the hole - one from each end. The key slot will face up on one side and down on the other. Your cable is now enclosed within the cylinder formed by the pair of retrofit fire safety nipples. Now screw them down into the panel from each end.

Figure 45 How to make and install a pair of **retrofit fire safety nipples** to reduce fire risk from short circuits in existing wired-through holes in sandwich panels.

Endnotes

1 (a) Hamlet Chicken Processing Plant Fire www.rorigas.com/hamlet chicken processing plant fire 2013-06.html 3 Sept, 1991; http://www.rorigas.com/] is no longer available, but a copy of the video is in the **Author's database as √ [Endnote (1a)] Hamlet Chicken Processing Plant Fire - What Is Health.pdf**
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22 At least 119 people perish in China poultry plant fire. Frame grabbed at time mark1:10] **Video available in Author's database as √ [Endnote (22)] At least 119 people perish in China poultry plant fire**

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25 Figure 20. Dhakatribune.com as published in inserbia.**info/news/2013/06/china-at-least-120-dead-in-fire-at-poultry-processing-plant/] Also available from the Author's database as √ [Figure (20)] InSerbia News June 4**

26 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 is 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 future technological developments allow us to use ordinary air as its final replacement.

27 Figure 25. 119 dead in Jilin poultry plant fire 06032013 18:15 BJT english.cntv.cn/program/newsupdate/20130603/105015.shtml] **Also available from Author's database as √ [Figure (25)] CNTV English**

28 Readers are advised to read the chapter on rendering within the handbook series on the Aptec website http://www.aptec.in to discover why the century old American concept of public rendering plants for large animal offal is grossly inefficient for captive rendering of poultry waste.

29 The Amino Acid Content and Availability of Different Samples of Poultry By-Product Meal and Feather Meal. ALFONSO BURGOS, J. I. FLOYD AND E . L . STEPHENSON. *Department of Animal Sciences, University of Arkansas, Fayetteville 72701.* POULTRY SCIENCE 53: 198-203, 1974. https://www.researchgate.net/publication/270070421] **Also available in Author's database as √ [Endnote (30)]The Amino Acid Content and Availability of Different**

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33 *Ibid.* IFIC Forensics – The Dangers of Sandwich Panel Buildings

34 *Ibid.* ChinaDailyAsia.com Investigators hunt for clues to fire

35 A Quonset hut is a light weight prefabricated structure of corrugated galvanised steel having a semi-circular cross-section. The design was based on the Nissen hut developed by the British during World War I and although an improvement over the original, it had serious drawbacks like difficulty in making windows and allowing proper circulation of air within it. The name comes from the site of first manufacture, Quonset Point, at the Davisville Naval Construction Battalion Centre in Davisville, a village located within the town of North Kingtown, Rhode Island, USA.

36 Popping a 5000A Fuse at https://www.youtube.com/watch?v=0mGhhdPgXG8,]. All four screen grans (figures 37, 38, 39, 40) have been taken from this video

37 Olfactory fatigue. OSHA Note on Hydrogen Sulphide. https://www.osha.gov/sites/default/files/publications/hydrogen_sulfide_fact.pdf

38 To know more about hydrogen sulphide hazards in poultry slaughterhouses, read APTEC Article on Reducing Slaughterhouse Waste-stream Odour at www.aptec.in

39 Tyson Foods fined $500,000 for worker's death. Watt Poultry USA, Release Date: Monday, June 15, 2009.

40 IFBS Galileo A Risk Analysis of Sandwich Panels, http://www.sandwichbau.de

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43 1000 evacuated in Tyson food plant fire, Fire Department: Explosion likely started fire, www.wlfi.com/generic/news/, 5 Mar 2010; Tyson Foods begins Missouri poultry plant expansion, http://www.worldpoultry.net/nr1, *May 1, 2012;* Woody Gottburg, Fire Damages Storm Lake Tyson Plant, Jan 4, 2017; Fire at Tyson Chicken Plant, Employees injured in blaze at Nashville's Tyson plant, Jul 9, 2020, https://www.ktbs.com/fire-at-tyson-chicken-plant/

44 Chicken Processing Plant Fires, Hamlet, North Carolina and North Little Rock, Arkansas, US Fire Administration/ Technical Report Series, USFA-TR-057/June/September 1991. Loss Prevention Bulletin of April 2018 as reported in a copyrighted article by the Institution of Chemical Engineers

45 *Ibid.* A risk analysis of sandwich panels

46 Alliance for the Polyurethanes Industry, http://inspectapedia.com/Energy/Polyisocyanurate_Insulation.htm

47 *Ibid.* 2(a) U.S. Fire Administration/Technical Report USFA-TR-057

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