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Design of Poultry Slaughterhouse – Layout, Geometry, Construction Methods & Environments

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Preface

[The topic Design of Poultry Slaughterhouse has been divided into three chapters, namely (1) Engineered Ventilation for Biosecurity & Efficiency, (2) Materials & Safety and (3) Layout, Geometry, Construction Methods & Environments. This is the third of these chapters].

This chapter is aimed at two levels of readers, including some of you who may be consultants charged with the overall responsibility of preparing plant layouts and plot plans. You would then yourself use a drafting program like AutoCAD for the job. Or you may be the plant or project manager, in which case you would take the help of a draftsman to do so and evaluate layouts prepared by him. If you are among the latter, you may need to prepare a draft layout using a simple flowcharting program and present the same to your draftsman or consultant to explain your preferences. If this is the case and you are unable to use AutoCAD yourself, you may use a simple drafting program such as Microsoft Visio[1] or, with some imagination, even Microsoft Excel, with the drag-and-drop feature enabled. Figure 10 shows how you may even use carefully and proportionally trimmed slips of paper to assemble the functional blocks of the proposed plant, dragging and positioning the slips to represent your ideas.

Preparation of a good layout plan involves observation of twenty-two rules and principles. Up to the end of section 1.1, we draw out the eight basic principles of layout planning. In section 2 we list six rules for preparing a plot plan. In section 2.2 with the help of these, we show how a plot plan and the contents of a simple process building may be designed. In section 4, after we have discussed the construction styles in use, we list an additional eight rules for preparing layouts for plants and plot plans. Table 1 shows the location of all twenty-two rules.

Table 3 presents a compilation of machines used in the process, their salient features, rules associated with their use and the state of design evolution that the machines are in at present. Figure 5 lists the principal processing steps and figure 8 shows the schedules that different activities and departments need to follow over the 24 hour cycle, encouraging you to break out of the shift operation paradigm for overall efficiency and economy. While table 17 lays down the design options for offsites and utilities buildings, table 18 contains a compendium of recommended construction specifications for the entire slaughterhouse facility. In sections 5 we show and discuss examples of advanced process building layouts.

Rules and preferred practices enumerated and discussed in this chapter	**Number of rules**	**Discussed in section**
Designing a process house	8	1.1
Designing plot plan	6	2
Additional construction system related rules	8	4
Total of all rules discussed in this chapter	**22**	

Table 1 Summary of rules for designing poultry slaughterhouses

Throughout this Handbook we have used example drawings from projects we have been associated with over a quarter of a century. We have used these examples to illustrate the mistakes and deficiencies in some of them, and the qualities of others, hoping to drive home important principles. We chose the method of illustrating design rules with examples of layouts instead of merely stating them, hoping that by doing so we could drive home the principles involved more convincingly and at the same time keep the narrative interesting, helpful and memorable.

We have noted the difficulty in presenting large drawings on an A4 page format, which this Handbook is composed for. When we complete the Handbook, we promise to upload all the drawings in their natural sizes as a zipped file to overcome this problem.

1 The Mechanised Slaughterhouse

All modern poultry slaughterhouses have a high degree of automation. Mechanised poultry processing started some time around or after the 2nd World War and popularity of chicken meat soared thereafter, always accompanied by easy availability and convenience. Automation of slaughter kept close pace with improvement of breeds, farming methods, nutrition and feed conversion ratios so that there was rapid growth in this industry. In 2021 annual worldwide poultry meat consumption stood at 133 million tonnes, set to rise to 152 million tonnes by the end of the decade, already making it the staple at a global per capita-annum consumption rate at between 16 and 17 kilograms[2].

But this industry has not always had such a high level of automation. At some time in their past, poultry processing plants started at more modest capacities, using a semi-automatic process. In industry parlance, a semi-automatic process refers to “a high degree of automation in all processing departments except evisceration (which, in the semi-automatic configuration, is almost entirely performed by personnel using pneumatic hand tools)”.

Full automation becomes necessary when the **line speed is increased to such an extent that manpower suited to work at such paces for the duration of a shift became difficult to find, recruit and train**. At high speeds human operators holding passive or pneumatic hand tools are unable to cope.

Semi-automatic plants can be expanded and upgraded by the replacement of work stations and manual or pneumatic hand tools with automation as the plants grow and the capacity warrants it. In our experience, the inflexion point is reached at 4000 birds per hour (BPH) or line speeds of 67 birds per minute (BPM). Below that capacity semi-automatic plants perform well; above it, the speed becomes too much for manual work.

There is absolutely no truth in the assertion that hygiene and quality are possible only in fully automatic plants. This belief probably owes its origin to irresponsible over-sell by equipment vendors. On the other hand, quality and hygiene may be impossible regardless of the level of automation if basic rules of layout design are not followed and periodic cleaning and maintenance is ignored.

Machines for configuration of processing stages in both semi-automatic and automatic plants are listed in table 3. The advisability, merit or otherwise of automation in each stage is specified there and Aptec’s views in respect of available level of automation at each stage is discussed.

Although mechanisation in this industry has been happening for a long time, not all departments have reached equal perfection or maturity in machine design and automation. Some have reached design maturity, others are still evolving. In particular machinery for live bird arrival, stunning, evisceration and portioning & packing are still undergoing evolution.

In line with this, table 3 also mentions Aptec’s perceived level of evolutionary maturity for specific departments and functions and also relates investment cost to choice of machinery and relative to operating capacity. We believe a knowledge of these facts is helpful in preparing or choosing good layout designs which we believe is the ultimate goal of this chapter of the Handbook.

1.1 Eight Steps To A Design Philosophy For Poultry Slaughterhouses

How does one go about designing a plant layout that suits the entrepreneur at the entry-level semi-automatic capacity and yet lends itself to seamless expansion to modern line speeds in the future? We ask this rhetorical question because poultry processing is highly scale-sensitive and one way to attain success is to keep expanding capacity.

To design a good layout one assesses the potential of the available piece of land[a] and determines the maximum line speed or plant capacity it can sustain in future[b]. One then draws out the boundaries of an initial plan[c] for that line speed or capacity consistent with the available funds as stage one, aiming to keep expanding till the plant capacity reaches the limit for that layout and piece of land. Finally, one completes the details of a plant designed to run at the starting line speed or capacity within these boundaries.

Note the terms and phrases defined by the superscript a, b and c in the previous paragraph - potential of the available piece of land, future and initial plan. We will return to them as well as the inherent merits of this design philosophy in the course of this chapter and expand on these ideas. But first we will identify the steps leading to a good plant layout design. We have made these steps sufficiently universal – you may use these concepts in any industry, not necessarily in poultry processing. They are essentially rules for industrial planning.

1.1.1 Step 1 – Nature Of Process - Is It Additive Or Subtractive?

First ask yourself, "Is poultry processing additive or subtractive? An example of an additive process is preparing a meal. You take a bunch of potatoes, chop them, then **add** oil, spices, other vegetables, garnishes and water to prepare a curry. This is an **additive** process. On the other hand, you prepare a plate of pineapple slices by a subtractive process. In this you grab a pineapple, cut off and **discard** the crown, shave off the skin and pips and trash them, remove the core and discard it, and then finally slice the remainder. You are left with pineapple slices. When you slaughter poultry, you follow a **subtractive process**, or use a dis-assembly line.

But when you pack portioned chicken, you follow an additive process because you have to bring in packing material and in order to do so you need to have a packing material day-store, a label preparation section and some sort of bar-coding system near at hand.

But how does all this affect the layout design? Because you are bringing stuff from outside at this stage, you also need to build structures and systems that prevent the ingress of vermin etc into your process area together with packing material. In this case, *inter alia*, you need to ensure that the packing material day-store does not open directly into the process area.

And because you are discarding stuff in the slaughtering process – stuff that carries bacteria and other contaminants, you need to hygienically, promptly and continuously remove them from the process area.

1.1.2 Step 2 - Identify The Process Steps And Machines To Suit

Unless you have studied and understood the process thoroughly, you will not be able to prepare a good layout. And to study the process you must begin by a careful and critical reading of the literature submitted by the plant vendors. You will find that these will often deliberately obfuscate certain details where they (a) either wish to hide some features or shortcomings of their design, or (b) where they wish to spare the reader confusion about relatively unimportant details or (c) where they have a pre-formed concept of the relative insignificance of certain process features which they feel are going out of fashion or are becoming obsolete owing to technological trends.

You must note everything the vendors' literature presents - features, facts, observed omissions and implied technological trends. Put them down in the form of a table such as the one presented in table 3 here. Or better still, copy and print the table, add a column to the right and note down your observations.

Next, carefully read table 3. We have compiled the essentials, in sufficient details to help you arrive at a conceptual understanding of how the process itself influences the layout, not just at present, but will do so in future when changing industry norms might cause your client to adopt newer arrangements. Many of the features listed here are simplifications of the actual situation, especially as far as they concern process areas like live bird arrival, stunning, evisceration and portioning & deboning.

Design approach for departments like live bird arrival, stunning, evisceration and portioning & deboning is strongly influenced by your choice of principal vendor - Marel, Meyn or Baader-Linco. And is further complicated if you work with more than one vendor and even more so when you consider the ongoing evolution of machine designs for these departments. These issues have been taken up in detail in chapters devoted to these processing steps - chapters which are mainly aimed at the expert designer/consultant. These chapters are under finalisation and ought to be uploaded by 2023 end.

Inset 2 Table 3 provides simplified information relating to choice of machines in some departments. Although the lay designer need not master these subtle vendor-dependent nuances, it is useful for him to be aware of them so that when he is in doubt, he may consult experts.

Watch the video titled "From Plan to Plant" on the Aptec website. It has a link from the home page. It covers small operations from 2000 to 4000 BPH, set in India. Not everything shown in this video is ideal, but it will help you understand the process.

Finally if you need to delve deeper into the subject, read up the features in one or more handbooks and consult industry experts – not just academicians but plant managers and supervisors with practical experience. A clearer picture will emerge. Keep editing your table as you make fresh observations or stumble across fresh possibilities. Eventually you will discover gaps in the vendors' narratives and your table will need additional rows for listing possible process steps that may not have been worthy of mention by them. You may even discover details which we have chosen to omit in table 3 for reasons of brevity and simplicity.

When you have satisfied yourself with the final draft of your table, and find no unanswered questions in your tabulation, you can decide which processing steps your design must cater for and which steps may be too unlikely for you to worry about. You will also have decided by then to allocate some physical space in your layout for possible processing variations that remain contingent at present upon indeterminate technological or consumer behaviour factors, but may gain importance through the lifetime of your proposed plant.

Now you have assembled all the material for preparing an **initial-plan.** All you now need is an idea of the proper floor area for each processing step. You have three ways to arrive at these - (a) talk to your vendor, experienced plant supervisors or consultants, (b) download the layout drawings bundled with AptecApp from the Aptec website and study them, and (c) scale the drawings included in this chapter. (When the entire Handbook gets done, all these drawings will be separately uploaded in a large format so that this task becomes easier).

Table 3 **Steps in Poultry Processing, Required Machines & How They Impact Layout Design**

	Department/Action step	**Comment**	**Technology status, cost***
1	**Lairage**	The ideal operation needs no lairage. Size depends on plant capacity and travel time between farm and slaughterhouse. Feed withdrawal is done at the farm: so ignore holding time as a design factor. But cater to thirst with fogging and fans.	Strong evolution
2	**Mode of transport of live birds**	Design varies by type of live bird containers used, which in turn is influenced by operation size and stunning method applicable in your country or chosen by you. Small & medium sized plants in South Asia use coop transport, electric stunning (at higher than line frequency) and linear hanging arrangement. Gas stunning & carousel hanging needs more space at this end. Refer chapter on Arrival, Killing & Defeathering[3].	Strong evolution in live bird hanging, stunning. Modularity in steps of 1000 BPH. Proportional.
2.1	**Arrival, stunning & hanging**		
2.2	**Electric stunning**		
2.3	**CAS stunning**		
3	**Killing & Defeathering Department**		
3.1	**Overhead line conveyor** with shackles, drive and lubrication system	In very small plants killing and evisceration may be combined in a single line as in figure 12. Although an acceptable compromise at low line speeds, this is not acceptable at higher speeds where manual cleaning of the line becomes difficult.	Modular. Not much evolution. Proportional.
3.2	**Water bath stunner**	Types of stunning have been covered in another chapter[4]. If stunner is not used for religious reasons as in Pakistan and Sri Lanka, strenuous wing flapping results in up to 25% wing damage. Islamic Fiqh Academy at Joga Bai, Jamia Nagar, Delhi advocates stunning in India and electric stunning at higher than line frequency is favoured at present. Select model to suit your final capacity – it can be adjusted to line speed.	Not modular. Evolving. Choice of model unaffected by capacity.
3.3	**Blood trough**	Use a stainless steel modular trough - design drawing can be provided by Aptec.	Modular. Proportional
3.4	**Jacuzzi or Jet Stream scalder**	Local machines under-perform in comparison with Jacuzzi or Jet Stream scalder. Steam scalder was a failed innovation. Steady temperature is the key to performance. Other design variations are (1) two and three pass arrangement, (2) steam or electrical heating, (3) direct or indirect heating and (4) scald time. Prefer two pass, indirect steam heating and between 80 and 120 seconds for jet stream and jacuzzi types respectively.	Modular design, cost & expansion in steps of 1000 BPH. No design evolution.

3.5	**Feather plucker**	Local and Chinese machines tend to underperform. A feather conveyor belt under the plucker bank is not essential – a floor gutter is enough to carry away feathers in the form of a slurry. Cylinder type pluckers are not used in India.	Modular - add machines of 1300 or 3000 BPH. No evolution.
3.6	**Head-puller**	For efficient evisceration it is necessary to pull off, rather than cut off heads. Simple design – no evolution.	Capacity limits for models.
3.7	**Hock or foot cutting**	Hock cutting is standard in India. Where a combined killing-EV line is offered, the hock cutter is placed at the end of the line - after evisceration. But if separate killing and EV lines are installed, it exists at the end of the killing line.	No evolution. Replace for automating rehanging.
3.8	**Hock unloading**	Basic model suits capacities of up to 4000 BPH and design is dependent on nature & source of killing shackles.	No evolution.
3.9	**Hock processing**	For peeling yellow skin for export to China, use local machinery in small operations.	
3.10	**Chain & shackle washer**	Essential for product hygiene. More so in a combined line.	Suits all speeds.
3.10	**Orientation**	Orientation in this and logistics in subsequent departments depends on your choice of two or three-pass scalder because hock cutting & unloading positions are diametrically different for the two.	-
4	**Evisceration Department**		
4.1	**Re-hanging**	Fully modular in steps of 2000 BPH when manually performed. Can be automated cost-effectively beyond 6000 BPH, at which time the re-hanging machine also takes over the function of a hock cutter.	Modular, with proportional cost down to 2000 BPH steps.
4.2	**Overhead EV line conveyor** with shackles, drive and lubrication system	Offered only where a combined line is not. Shackle pitch of 12" and 6" are possible (see section 1.1.7 for explanation).	Modular. Not much evolution. Proportional.
4.3	**Evisceration trough or belt.**	In semi-automatic evisceration the action is performed with the use of pneumatic tools over this trough/belt. If you choose trough, it can be locally fabricated to Aptec design	Modular. No evolution. Proportional.
4.4	**Hand Tools (for evisceration in small plants)**		
4.4.1	**Pneumatic vent drill**	Pneumatic tool for cutting around cloaca without damaging the bursa and without spilling contents of the gut into the body cavity.	Not modular. To expand add machines, resulting in proportionality. No evolution.
4.4.2	**Pneumatic, vacuum lung pistol**	Pneumatic tool for removal of lungs and tissue debris from the body cavity.	
4.4.3	**Gizzard peeling**	Removes the inner horny yellow skin of the gizzard.	
4.4.4	**Pneumatic neck cutting scissors**	Used only where the customer wants carcasses with neck off. Not used in India.	
4.5	**Automatic Machines (for evisceration in larger plants)** For all these machines except 4.5.1 there are different models that allow you to operate at their 100% or 50% rated capacities. Then there is partial price proportionality.		Partially modular, partially proportional.
4.5.1	**Carcass washing system/Automatic washer**	Outside washing spray cabinet, locally fabricated to Aptec design for small plants. For larger plants automatic inside/outside washers are necessary. (See section 1.1.7)	No evolution.
4.5.2	**Automatic crop removal machine**	One of the automatic evisceration machines which does a more thorough job than manually possible. Aptec recommends it from 2000 BPH onwards (See section 1.1.7).	No evolution.
4.5.3	**Automatic vent drill machine**	One of the automatic evisceration machines which does a more thorough job than manually possible. Aptec recommends it from 4000 BPH onwards.	No evolution. Marel's combined action models are promoted in developing world.
4.5.4	**Automatic opening machine**	Different models to suit different processing styles beyond 3000 BPH. Models for different opening actions are available.	
4.5.5	**Automatic evisceration m/c**	Two styles exist – spoon type and hinged type with varying performance results. Different sizes to suit different capacities.	Not much evolution
4.5.6	**Giblet harvesting machine**	Several automatic and semi-automatic models available from all vendors. Performance & yield influenced by farming method.	
4.5.7	**Automatic neck machines**	Models for processing carcasses with neck and neck skin removal are available. Irrelevant for Indian market.	
4.6	**Chain & shackle washer**	Essential for product hygiene.	Suits all line speeds

5	**Chilling Department**		
5.1	**Spin or screw chilling**	For rapidly cooling carcasses cost-effectively for good shelf-life, far exceeding results from ice slush tanks. Local machines generally ignore counter-current flow and give poorer results. Available in steps of 1000 BPH at 2100mm dia shell.	Modular. Cost is almost proportional.
5.2	**Air chilling**	Less cost-effective than spin chilling. Not used in India.	-
5.3	**Dewatering or dripping system**	Small plants use locally made drip racks, progressing to spin extractors in Marel lines. Where weigh-line is installed, Aptec recommends extending it for dewatering by simple dripping.	Modular. Mature. Proportional.
6	**Weighing and Grading Department**		
6.1	**Rehanging conveyor**	Can be locally sourced. Factor one person for each step of 2000 BPH.	Modular. Proportional. High level of evolution.
6.2	**Table-top weighing machines**	Electronic weighers for manual weighing and grading of portions, whole carcasses, and tray packs.	
6.3	**Automatic weighing & grading line or machine**	Computerized , highly accurate weighing/grading for batching into from 8 to 32 weight categories. Less accurate batching accompanying free giveaways possible with belt graders.	
7	**Secondary Processing and Packing Department**		
7.1	**Packing table**	SS tables locally fabricated to Aptec design. To be used for portioning, deboning, grading and packing.	Modular, mature, proportional.
7.2	**Carcass bagging**	Used for wicket bagging whole carcasses. Locally sourced bagging horns for small capacities and semi-automatic bird bagger from Meyn for the rest.	
7.3	**Disk cutter**	Locally made machines for curry-cuts, portioning carcasses.	
7.4	**Cone deboner**	Versatile machine for producing large quantities of portions and breast fillets with throughputs starting at 700 BPH.	
7.5	**Japanese cut-up line/J shackle line**	A larger and more efficient system than the cone deboner for a capacity of up to 3000 BPH.	
7.6	**Automatic cut-up machines**	Several models available from all vendors. Only a few such systems are in use in India because of their lower yields. Cheaper local manpower generally offsets their advantage. At higher capacities, combination of compact cut-up systems with cone deboner & Japanese cut-up lines suitable for India.	Partly modular, Evolving, Not proportional.
7.7	**Packing machines**	A large variety of tray-packers available locally.	Proportional.
8	**Auxiliaries**		
8.2	**Offal handling section**	Processing waste removal as slurry via floor-gutter system and gantry mounted pipeline to rendering building is suitable for India. Neither machine is available locally. Manual handling of offal is undesirable.	Not modular.
8.3	**Crate washing section**	Two coop sizes are used and match locally made machine. Automatic crate washing reduces manpower and ensures consistent and hygienic operations.	Not modular. Capacity based on crates/hour.
8.4	**Steel superstructure**	Required for suspension of overhead conveyors in the Inflexible Block. Typically made by bolting together dip-galvanised 'I' sections of 70x125mm. The superstructure itself rests on partition walls & suspended by Aptec design ceiling anchors embedded in the RCC roof slab.	Modular, proportional. No evolution

NOTES

* This column provides information about technology status in this manner:

Mature/evolving whether the technology is undergoing change or is **evolving** and if so whether changes in technology are expected during the life of the plant you are planning. Must make note of this in terms of changes in space requirement, processing parameters etc. Where it says **Strong evolution**, you need to educate yourself on the subject and make your layout ready for future shocks within the useful life of your plant.

Modular whether design of the machine or system allows you to implement changes as your capacity grows. If not modular, with changes in capacity you must scrap existing machine and opt for a newer, higher capacity machine. Local and many Chinese machines like screw chiller, scalder tend to be non-modular.

Proportional whether modification to meet increased capacity objective raises cost roughly proportionally.

When you face a dilemma about space allocation to cater for evolving technology, look at the five sample layouts bundled with AptecApp, where areas are specified. Further, if you are not familiar with the footprints of machines in illustrations in this chapter, examine the bundled layouts. There each machine footprint has a number that links it to a legend. For a larger plant with carousel hanging and automation in that section, refer to figure 9 which lists the areas for a large plant located in north-central Europe.

While your are doing all this, people will want to know what level of automation you are considering. The choice of automation is most strongly influenced by your line speed and least influenced by concern for hygiene and product quality. The phrase "touched by hand" in itself can scarcely be treated as a pejorative. Worldwide, even in those plants that have automated with a vengeance, human contact occurs - not just in the dirty and unpleasant departments that perform scalding, defeathering and evisceration, but most definitely, also in the post- processing stages such as portioning and de-boning, packing, inspection and so on – stages after which the product cannot be washed or disinfected any more! This is the irony of the pejorative associated with "touched by hand"!

Table 4 **Automation Of Evisceration In India (circa 2022)**

	Level of automation	**Operating and planned plants in India**
1	Plants with 4 or more machines (including plants with "multipurpose **" machines which perform all or many of these 7 actions)	Shanthi, SKM, Sneha, VH Davangere, VH Taloja, Godrej Taloja, Godrej Hoskote, Sivasakthi. (The last three, were supplied by Marel, who sell several models of "combined action automatic machines" in Asia and Africa**)
2	Plants with 1-3 automatic machines	Approximately 17 plants. They are listed in table 1, part A of a contemporary Industry Report on Aptec website.
3	Plants with no automatic machine at all	All remaining plants in table 1, part A of a contemporary Industry Report. This includes plants supplied by Alpha Food & Poultry, Bayle and indigenous plants of Deccan Automation, Dhopeshwar, RND & Storm Engineering.

** Marel plants in India and much of the developing world contain several examples of such combined-function machines. By definition combining functions reduces the machine count and therefore part of the cost, but it makes these machines difficult to set or adjust. In a processing plant in South Asia, a total of 7 automatic machines deployed in the evisceration department makes it "fully automatic". These machines/functions are (1) vent cutting machine, (2) opening machine, (3) eviscerating machine, (4) giblet harvesting machine(s), (5) cropping machine, (6) final inspection machine and (7) inside-outside bird washing machine. Neck breaking & neck skin trimming machines are not relevant to processing for the Indian market.

Of all processing steps, at some stage as you expand, automation of evisceration becomes most important – most of the remaining departments already have a sufficient level of automation. As mentioned above, full automation of evisceration becomes a necessity beyond a line speed of 4000 BPH. Below it, and at it, full automation may be gainfully avoided without any ill effect, provided skilled labour is available and labour productivity permits it. However, paradoxically, there is now a well perceived creeping shortage of labour in India, as there was in China, a decade ago. So an examination of the level of automation in evisceration in India at present may settle doubts. Table 4 has the information. Additionally your layouts must allow space for a future upgrade with automatic evisceration, whether necessitated by capacity or shortage of skilled manpower.

1.1.3 Step 3 – Determine The Process Geometry – Is it Linear or Branched?

The physical nature of what you propose to process impacts your layout seriously. You need to ask yourself, "Is your raw material granular or fluid, thus lending itself to flow in a pipeline to be conveyed through the production process, moving right or left, up or down and forward as it undergoes conversion into finished products. If this is true, then we can safely choose the plot of land in figure 6, with its unusual aspect ratio.

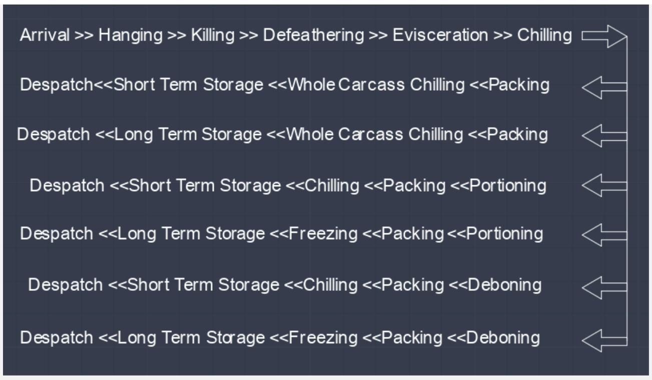


Figure 5 Determine whether the progression of individual process steps follow a linear or branched pattern. The above steps can be further subdivided – once you create a mental image of the actions needed to carry them out. You will find that the pattern closely reflects upon the physical allocation and positioning of spaces for the individual process steps and realise why the layout in figure 6, being essentially linear, falls woefully short of the ideal.

On the other hand if your raw material is not granular, but lumpy and irregular (as chicken are), then not only is your raw material not amenable to piping or linear transport through the process area, but requires the process flow itself to branch out at several stages. You therefore need a plot of land with a more reasonable aspect ratio.

Furthermore, for technological reasons, in a poultry slaughterhouse these various branches move at different speeds, and cannot be sped up or slowed down or placed on hold for any length of time.

While freezing of poultry imparts a very long shelf life to it, (as much as a year, according to ASHRAE, and this plays a vital role in stabilizing prices), there is a worldwide trend favouring fresh-chilled poultry. Fresh chilled poultry has a short shelf life – typically 4-5 days, provided the cold chain from the processing plant to the consumer's refrigerator is intact. Your effort has to concentrate on processing poultry for the fresh chilled market as rapidly as possible so that as much as possible of this short shelf life is available at the store shelves and in the consumer's refrigerator rather than get frittered away in your plant and on the road. With a simplistic linear process-flow shown in figure 6 you will find it hard to meet this objective. The linear flow concept may serve vegetable oil processing or feed milling, or several other such industries, but will fail miserably in this industry.

The layout design shown in figure 6 was drawn by the chief of a large industrial house and a new entrant to the poultry processing industry around 1999-2000 for a site close to Bangalore. Primacy of location was reserved for the office block in the plan, while production and logistic areas were force-fitted into narrow spaces. In other words this plan ignored the design philosophy we are in the process of developing in this chapter. Vendors were required to comply with this layout that suited a long and narrow piece of land.

Within three years of operation Aptec was invited to perform an audit to locate and solve operational bottlenecks. Based on Aptec's report of 20 July, 2003, the company purchased an adjacent plot of land and on the wider, consolidated site, a new plant was constructed to replace the existing one. This time the layout was not drawn by a lay person.

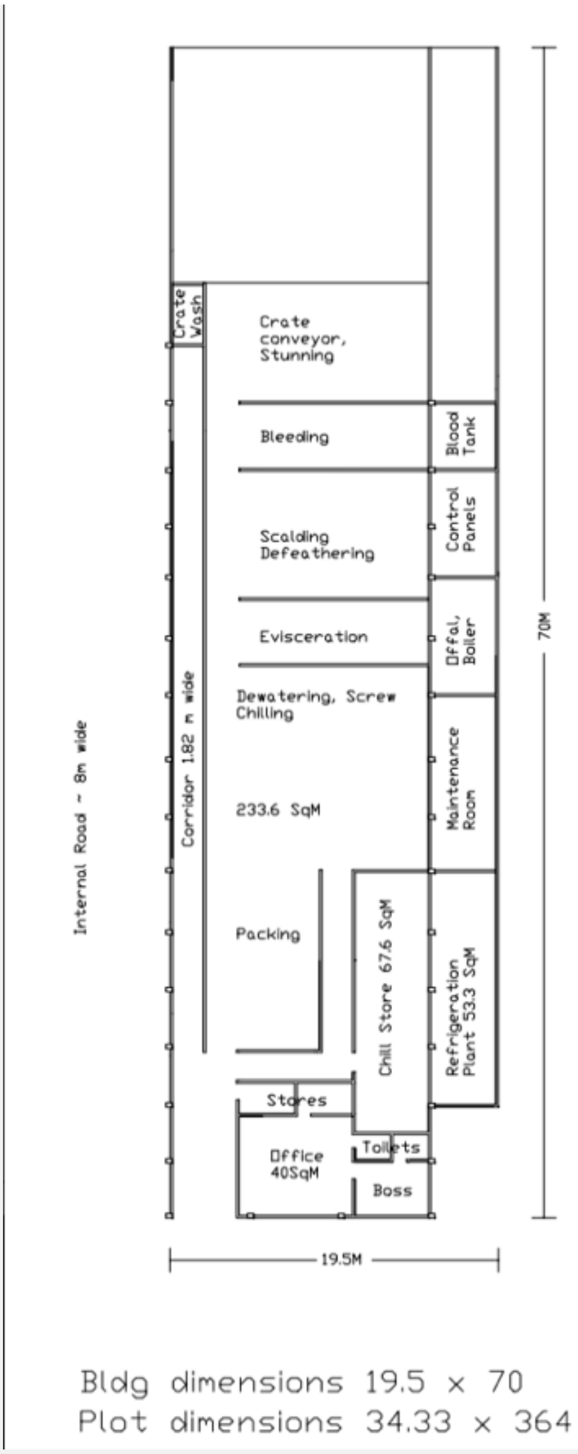


Figure 6 Showing an 1:3.5 aspect-ratio layout of a 1000 BPH poultry slaughterhouse designed for an 1:10 aspect ratio plot of land. This design owes its outlandish features to the then chief of the company that built it, sometime in 2001.

1.1.4 Step 4 - Identify Special Features.

In the poultry slaughterhouse, arrival of live birds is the dirtiest step. From here on, we progressively move into cleaner and cleaner steps and to maintain hygiene ***the dirtiest areas are always placed farthest from the cleanest areas***.

(1) Here we have stated one special feature of poultry processing – **it incorporates a gradient of cleanliness** – from the dirtiest to the cleanest and the sequence must be maintained in your layout. Also, for aesthetic reasons, try to place the dirtiest end farthest from the access road to your premises.

Since the shelf life is short you need to move the product as quickly from the plant as possible. Every aspect of poultry processing and marketing must ensure that the product moves rapidly down the chain. In so far as this relates to the design of a processing plant, one has to ensure that there are no waiting steps – ***all poultry, whether whole or portions, must move rapidly through the production steps.*** (2) Here we have stated the second special feature.

How does freezing stabilize prices? Poultry is a perishable produce – once the day-old chicks are housed in commercial sheds, they need to be harvested, killed and processed within a certain number of days by which time they will have attained the desired live weight. When they are left in the farm sheds longer than desired, they become heavier. For gaining that extra weight they will have consumed more feed and as the weight increases, the unit price must fall[5]. (3) This is the third special feature. In order for the farming and slaughtering activities to match, there should be cooperation between companies performing them. This does not happen in India because there is a monopoly situation in breeding poultry and the monopolist tries very hard to maintain his position by fine-tuning gluts and shortages to block competition to breeding.

Since live bird prices are unstable and subject to large swings, there will be times when live bird prices crash and in such periods the processor must process, freeze and refrigerate large quantities of carcasses. He does so by over-speeding his plant and operating extra hours. Then when prices stabilize, he can sell whole frozen carcasses at a super profit or produce portions to be sold as fresh chilled product. To do so he passes the frozen carcasses through his screw chiller, using ambient temperature water this time, portions the thawed carcasses and ships the portions to the market.

Figure 7 A toll plaza. Notice how the number of lanes multiply several-fold to reduce traffic hold-up

If his plant is incapable of over-speeding or his freezing and storage capacity has limitations, he will not be able to take advantage of price gluts. Therefore with your design you must help him to make super-profits during gluts. Your plant design must therefore have extra stamina - bleeding lengths should be adjustable, there should be extra spaces for hanging, bleeding, evisceration, portioning and packing. Your flake ice machine must be over-designed. Finally, the blast freezing capacity must be designed for running extra hours and there should be space for expansion of your frozen store. In effect none of your machines must exactly conform to the nominal plant capacity. (4) This is the fourth special feature.

1.1.5 Step 5 – Cater To The Special Features

Motoring on a highway, you will have noticed how the tarmac widens by four or five times, or a four lane highway widens enough to accommodate sixteen or twenty lanes, each leading to a toll gate. Why would highway planners do that? Simply because they realize that the traffic will slow down at the toll gate, so, to reduce obstruction to normal traffic flow, they have four or five times as many lanes at a toll gate. Poultry processing is like a traffic of chicken carcasses and its portions flowing through the plant. The flow must be rapid because speed equates to scale economies and obstruction to flow results in poor economics and reduced product shelf life.

However, different steps in the process take different amounts of time. In fact the processing steps from killing to chilling are very quick – as rapid as the plant vendor guarantees. It may be, say, 8000 BPH in your case. But after chilling and weighing-grading of whole carcasses, traffic slows down considerably. This is so because a lot of the work needs to be done manually in these steps. Even when you deploy plenty of automation in the portioning, deboning & packing department, (which are essentially the steps left over after initial weighing-grading), you still have to prepare shipment lots to suit individual customers. Each customer has his own laundry-list of quantities and specifications, so you essentially have a potential traffic jam in these steps. How do we solve this in terms of layout planning. ***We widen the traffic flow in these steps, just like a highway engineer does.*** (5) This is the fifth special feature.

But there are space restrictions in the way. Remember, the portioning, deboning and packing hall cannot expand sideways in step with growth in capacity because this hall is typically surrounded by service and utility sections along its sides, which cannot easily be relocated. These comprise (a) the packing material store, (b) the returned-crate-wash and holding area, (c) the row of blast freezing chambers, (d) the row of frozen stores and fresh chill stores with dispatch corridor and despatch bays. Most of these need to be close to the portioning, deboning and packing hall and are connected to a network of refrigeration pipes. If you wish to relocate all or some of these to create space for expansion, you will incur a lot of downtime, redesigning of the refrigeration system and cost. We will use the phrase '**Extrudable Block'** to refer to these sections. This phrase is explained further in the glossary and discussed in section 3 on construction methods.

In designing the Extrudable Block you have to consider the final positions of all these and yet leave enough space for expansion of every utility and service. Your plan must include ***extrusion*** of the building in the direction of product flow – not at right angle to it. At the outset you need to ***determine the planned width of the truss-roof building*** that houses the Extrudable Block and maintain that width as a permanent feature or the ***extrusion width of your design***. And as you expand, this truss roof building extrudes in the direction of product flow. Figure 14 explains this. You will realise with experience that every strategy for expansion other than extrusion will achieve sub-optimal results.

The same design problem that made us think of extrusion, also relates to the killing, EV and primary chilling departments, but in a diametrically opposite way. The process flow is linear here. But on both sides of the process flow you need to interface with the outside in terms of rest rooms for workers, an array of utilities including offal pit and pump, compressed air and vacuum system machinery and control panels for the entire plant. Once established, these cannot be easily relocated. Furthermore you may read in the chapter on Design of Poultry Slaughterhouse - Ventilation for Biosecurity & Efficiency, that any structural modification of components within this area seriously affects the air flow and hence hygiene and product quality. We use the phrase **'Inflexible Block'** to define this block of workspaces.

Therefore the inflexible block ***should likewise be assigned a planned width corresponding to the maximum achievable capacity of the plant*** at the outset. There will be no structural changes in these departments. You will only rearrange existing machinery or add more machines – every such rearrangement and addition must be foreseen by you at the planning stage. To be able to do so you need to study table 3 carefully to gain familiarity with trends in the industry with respect to specific machines and evolution in their design.

Consider, for example a possible change-over from coop based delivery of live chicken to drawer or container based delivery over the life of the plant. This may become necessary when you change your stunning system, for instance. You need more space for these changes. So if you have failed to set aside enough space for this purpose in the arrival area, you will not be able to make the change. Similarly, imagine that water chilling loses popularity and the client wishes to adopt partial or complete air-chilling. Once again you will need additional space for air-chilling. Of course, if you have followed Aptec's recommendation to install an RCC slab roof over the Inflexible Block, you will not face any difficulty in this case. (5) This is a repetition of the fifth special feature.

1.1.6 Step 6 – Break Out of The 'Shift-Operation' Paradigm

Ask yourself, is it possible or advisable to arrange the process branches of figure 5 serially or must we arrange them in parallel. In other words, can you perform the main processing action in the primary shift and all six branch processes of figure 5 in parallel, starting in the first and extending into the second shift. If it is possible to do the latter, we can try to use some of the shop floor area and a considerable number of machines and utilities twice in a day and so better utilize our assets.

How does operating assets for longer hours per day result in their better utilisation? Let us take the installed refrigeration system and installed electrical sub-station as examples. Let the installed refrigeration capacity be 500 tonnes (500 TR or 1758 kW of refrigeration capacity) and the installed sub-station capacity be 750 kW. These are deliverable peak capacities. If operated for the entire day at these peak levels, the delivered values would be cooling of 12,000 TR of refrigeration (24x500) and electrical energy of 18 megawatt-hours per day (24x750 kW). It then stands to reason that if you operate every department for only 8 hours per day, you utilise only a third of the peak deliverable in each case.

But naturally, you cannot run the entire plant at peak capacity for 24 hours a day. There are several reasons for this. Firstly, if you did that, there would neither be an opportunity to clean the plant thoroughly, nor any time for maintenance and troubleshooting. Furthermore, the process itself places time constraints because it takes far longer to portion & pack and freeze a thousand chicken than it takes to slaughter them. And all such activities must run in parallel or close to parallel for reasons cited earlier. So you need to stagger the operating hours of various departments in the manner shown in figure 8 to achieve the best results. And when you do so, you move entirely away from the standard shift-operation paradigm.

In processing poultry you cannot divide or segregate departmental functions into shifts because these functions must run seamlessly to prevent spoilage and the objective is to deliver a safe product with the maximum residual **shelf life** to retail stores. Figure 8 shows meticulous staggering of departmental schedules to optimise all these mutually conflicting objectives. If you follow the general method of staggering activities as shown here, you will achieve an optimum output for a given capital investment.

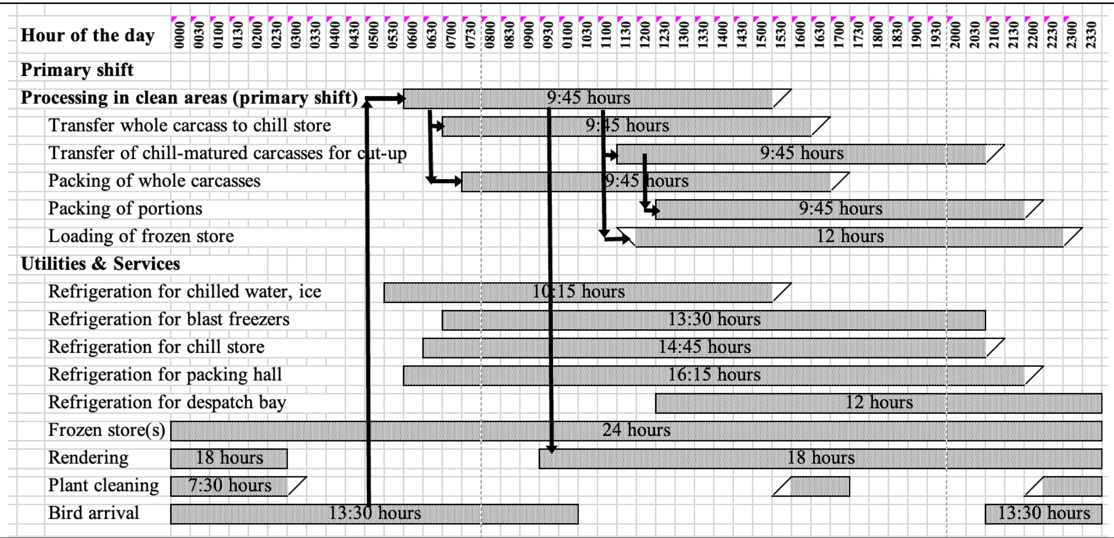


Figure 8 Desirable staggering of work schedule at a typical poultry slaughterhouse. This is how the process looks when you break out of the shift operation mental framework.

Of course, the schedule will need adaptation to suit your specific project. For instance, here the primary shift begins at 0600 hrs – you may choose a different time. Live bird arrival and lairage is shown to occur mainly during the cooler hours at night and the duration of this activity is deliberately made long to match feed withdrawal over farm sheds. The duration would also depend in your case on the distance birds need to be transported. So the schedule is subject to change, except that you need to observe the linkages of activities and ensure that activities at your plant effectively use all available hours, all day long.

Once you have finalised the schedule, your refrigeration vendor can use it to effectively plan his equipment configuration and also specify standby capabilities. So also can the HR department cater to the manpower needs, recruitment and roster and plan overtime payments.

1.1.7 Step 7 – Prepare A Phased Growth Plan

Imagine that your initial capacity is 3000 BPH and you wish to make a master layout with a peak capacity of 6000 BPH. Also assume that expansion of capacity is proposed in two stages: from 3000 to 4000, then to 6000 BPH. After that, if the market requires, the capacity may be doubled by taking up a second shift of operation. To avoid market-disruptive expansion in this manner (i.e. causing over-supply and consequent pressure on margins), the doubling of shift can be gradual, for instance, first by operating a second shift every second day, or by running 1.5 shifts every day, and so on, subject to labour laws.

In this case you will begin with the installation of three automatic machines viz. cropping machine, inside/outside washer and set of machinery for giblet processing in the evisceration department. For the first two mentioned automatic machines, you will choose models which are capable of operating at your peak capacity, i.e. 6000 BPH, but on initial installation they must perform at half that capacity because the line will have shackles at 12” pitch and the cropping machines will also have half the total number of operational units, also placed 12” apart from each other.

Later, when you progress to 6000 BPH (or even to 4000 BPH), you will add an extra shackle between the existing two and emerge with a shackle pitch of 6” in the evisceration overhead conveyor line. Correspondingly you will also mount extra operational units (or just units, in the parlance of the vendors) in the cropping machine to match the 6” shackle pitch.

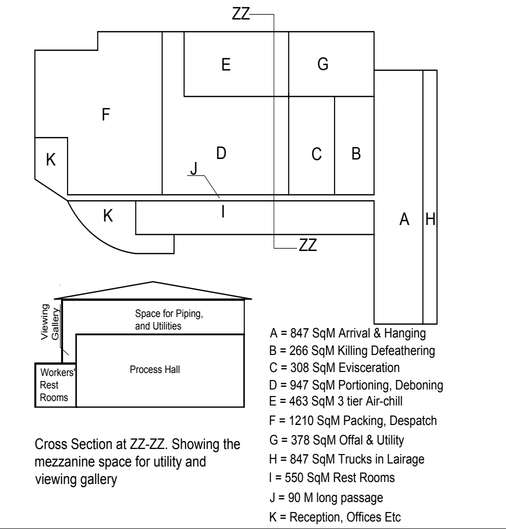


Figure 9 Space allocation within a 9000 BPH processing plant in north-central Europe. ‘A’ shows arrival and lairage and ‘H’ is the road that trucks follow into this area. Both A and H are under a common roof so as to function in inclement weather. Note also how the outline of the building departs completely from the square building paradigm even in a heavy snowfall area.

Because the capacity of automatic evisceration machines corresponds to the live bird numbers to be processed, so all such machines manufactured by Meyn, Marel and Baader-Linco, are designed for 6” shackle pitch for up to 15,000 BPH[6] and for each such machine the capacity can be halved by using a 12” pitch.

The delivered machine capacity depends on the number of units mounted along the circumference of its master-wheel. How is this achieved? You identify master-wheel circumferences for different diameters such that they are exactly divisible by 6” or 152.4mm. From this lot you choose those wheel circumferences that can hold an even number of units. Now the machine models are built with master-wheels of such exactly-divisible circumferences. For instance, the smallest Maestro eviscerator has 12 units, and the biggest model has 28 units. Why should the number of units be an even number? Because if it was not so, the machine would be unsuitable for a line with 12” shackle pitch.

But we mentioned the need for three automatic machines and we only talked of the cropping machine above. Why? Because the capacity of the inside/outside washer remains unaffected at these BPH ranges and in the case of giblet processing you will need to install an additional set of machines[7] when you exceed 3000 BPH. Look at table 3 and note the comments against these machines.

1.1.8 Step 8 - Determine Space Requirements

Now you must dimension the tentative layout by putting in place **scale footprints** of machines, functional areas, logistics pathways, working spaces, utilities and services. The last named includes workers’ rest rooms, canteens and other facilities and utilities include control room, air compressors, vacuum systems, maintenance space and input sections like packing materials day store, chilling and blast freezing areas, returned crate wash and so on. Besides allocating footprint spaces for machines, their physical orientation, mirror-ability and variations depending on vendor, you also have to follow industry standards even for dimensioning such mundane features like corridors, doors, windows, lighting, and ventilation.
Figure 10 shows a useful method of visualizing a layout. This method may be used for planning the plot plan as well as the interior of the process plant building.

You are now nearly ready to prepare a draft plot plan and the interior of your process building.

Besides the eight rules enumerated here, there are six rules or principles for making a proper plot plan and an additional eight rules and principles that relate to the method of construction you use. But to appreciate and understand them we need to explain them in the context of plot plan and construction methods. They have therefore been discussed later in this chapter.

2.0 The Plot Plan

2.1 Rules For Assembling The Blocks Within A Plot-Plan

Since it is not a linear process, at the outset you must select a plot of land with a smaller aspect ratio – something like 1:1 or 1:1.4, but definitely not 1:10 as shown in figure 6. Within that plot of land, taking note of cardinal directions if you have to comply with halal rules, and of the position of the access road, you build simple blocks denoting the various components that comprise a poultry slaughterhouse. You then interconnect the components with internal roads.

What are the dimensions of the various components that make up such a plot plan? Study the five layouts that come bundled with AptecApp from the Aptec website. Appropriate size of components are mentioned in these drawings. Use these dimensions as a guide. Once you have done so, use these principal rules for assembling functional blocks in a plot plan. You may use the method described in figure 10.

Figure 10 This picture[8] best illustrates the process of assembling blocks together to prepare both a plot plan and a process building layout.

Leave sufficient space for making a lagoon for storing and **treating waste-water**[9]. You will find this topic covered in other chapters[10] of this handbook, but essentially, for India, there cannot be any thumb-rule for the size of land area required for this. You need to consult your local pollution control board for help.

(2) **Design for safety against major mishaps.** One cause of major mishaps is neglect of fire hazards owing to incorrect placement of buildings, machinery or structures. To save yourself from such blunders make sure that the central refrigeration plant room and rendering-cum-steam-generation blocks are located a road-width away from the main process building. It should be possible for a truck or fire tender to enter that road. Figure 11 is an example of a plant layout where this was ignored, and because *the devil does not sleep***,** this plant is now a major mishap waiting to happen.

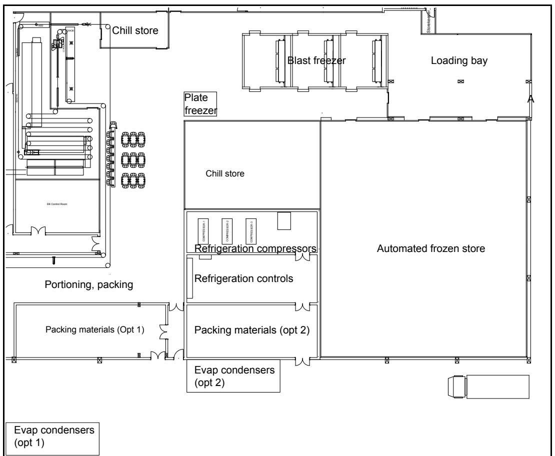


Figure 11 This layout, for expansion of an existing facility, shows two options for position of packing material store and evaporative condensers. The client backed option 2 in which the former almost blocks the escape route for workers in the refrigeration plant room in the event of a fire, simply because an existing contract with the vendor reduced his piping cost with this choice! Close clustering of all cold areas including automated frozen store and portioning & packing area - with escape routes blocked on three sides, adds to the risk. Remember also that a packing material store contains combustible materials.

(3) **Pipelines and possibly even cables between buildings are placed over a gantry** which connects these blocks to the main process building. You cannot move offal slurry from the process plant to a rendering block through an underground pipeline. The default choice of material for such a buried pipeline is invariably a Hume pipe (spun concrete pipe) and here is the problem – an anaerobic condition prevails within the pipeline and a facultative bacterium called *Thiobacillus concretivorus* generates hydrogen sulphide gas when it uses sulphur from calcium and magnesium sulphate, which are present in Portland cement, as an oxidizing agent, just like air breathing creatures use oxygen for that purpose. Hydrogen sulphide is an extremely dangerous and lethal gas and it generally accumulates in lethal doses in the offal pit room and slurry filtration areas of a rendering plant.

(4) There are rules for expandability of different sections within the slaughterhouse. These have been covered in detail elsewhere, with respect to the size of the arrival, killing, defeathering, evisceration and water chilling block. We have referred to this as the **Inflexible Block**. You must design them from the outset for the final expanded capacity of the plant. The arrival area may, at your discretion, be large enough to accommodate a gas stunning feature in place of electric stunning. Read chapter on stunning[11] to understand this.

Likewise read sections 1.1.5 and 3 to understand the concept adopted for expansion of the remainder of the process building, which we have called **Extrudable Block**. To sum up, **use the Inflexible Block and Extrudable Block definitions to design the processing building,** leaving enough space in your plot plan for extrusion.

(5) Always begin with a standard grid for the process building and try to **align other buildings and structures in the piece of land to an extension of this grid**. All columns must stay on the grid. If you use varying grid spacing, during construction there will be mistakes - Murphy’s law will ensure it. And no, errors may not just cause over-spending on construction in terms of over-design of columns and structures and rebuilding of wrongly placed columns and structures. It may even result in under-designed columns and structural members, waiting to fail catastrophically at a later date.

Grid spacing will vary according to machine and working space requirements and choosing a suitable grid spacing at the outset is a matter of intuition and experience. Aptec generally uses 6, 6.5 and 7 metres as grid spacing, with columns at the intersection of grid lines in the Inflexible Block and half as many columns in the Extrudable Block because the roof in that part is lighter. Study figures 13, 30 and 33 to learn how this objective is achieved.

(6) Always **begin a layout drawing with the final capacity**. Then, using the equipment placement and position of walls and partitions drawn to suit it, fit the initial capacity machines into it. By doing so you can ensure hassle-free expansion without having to break down or dismantle anything. If you are not making the layout drawing yourself, but expect your vendor to supply it to you, insist on receiving both drawings, with the initial capacity layout shown in detail and the final capacity layout embedded therein as an inset.

By way of an example, if you have sought an offer for, say, a 2500/6000 BPH plant from a vendor and he supplies you the offer and layout for only a 2500 BPH layout, he is taking liberties with you and has not thought the thing through. Chances are that when it is time to expand he will demand a lot of realignments and dismantling – not through any fault of yours but simply because he was lazy to begin with.

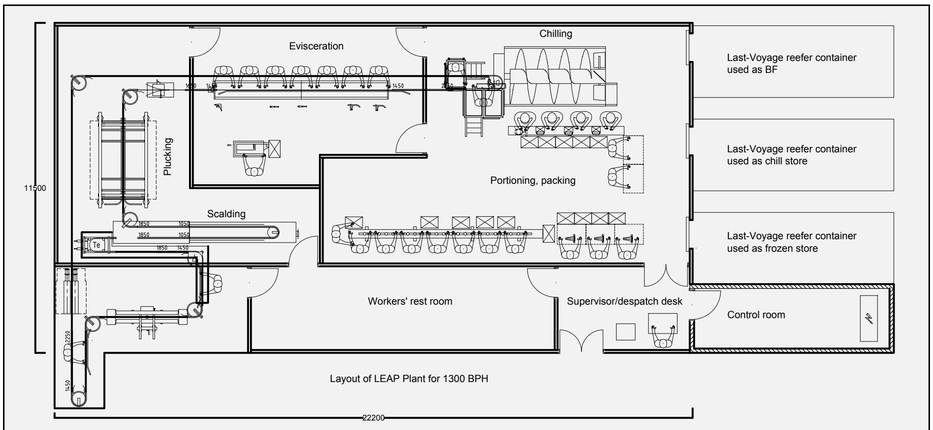


Figure 12 This is a slightly modified representation of the original LEAP layout for a 1300 BPH plant designed by the author in 2011. It is built on a tiny plinth of 255 SqM which is later, on expansion, incorporated into the floor of a larger plant. Except for the electrical control room, walls are of cam-lock type sandwich panels. Freezing and storage is done in last voyage reefer containers in which the plant equipment was received. Panels and machines are all dismantled in 2 days and re-assembled as part of a larger plant when you want to expand.

These then are the first set of rules to follow for plot plans. In section 4 we enumerate some additional factors that affect the layout, geometry and construction of your slaughterhouse and other buildings. But to understand them you must learn more about construction methods.

We will now begin the exercise of drawing actual layouts with the smallest possible capacity of 1300[12] BPH LEAP plant.

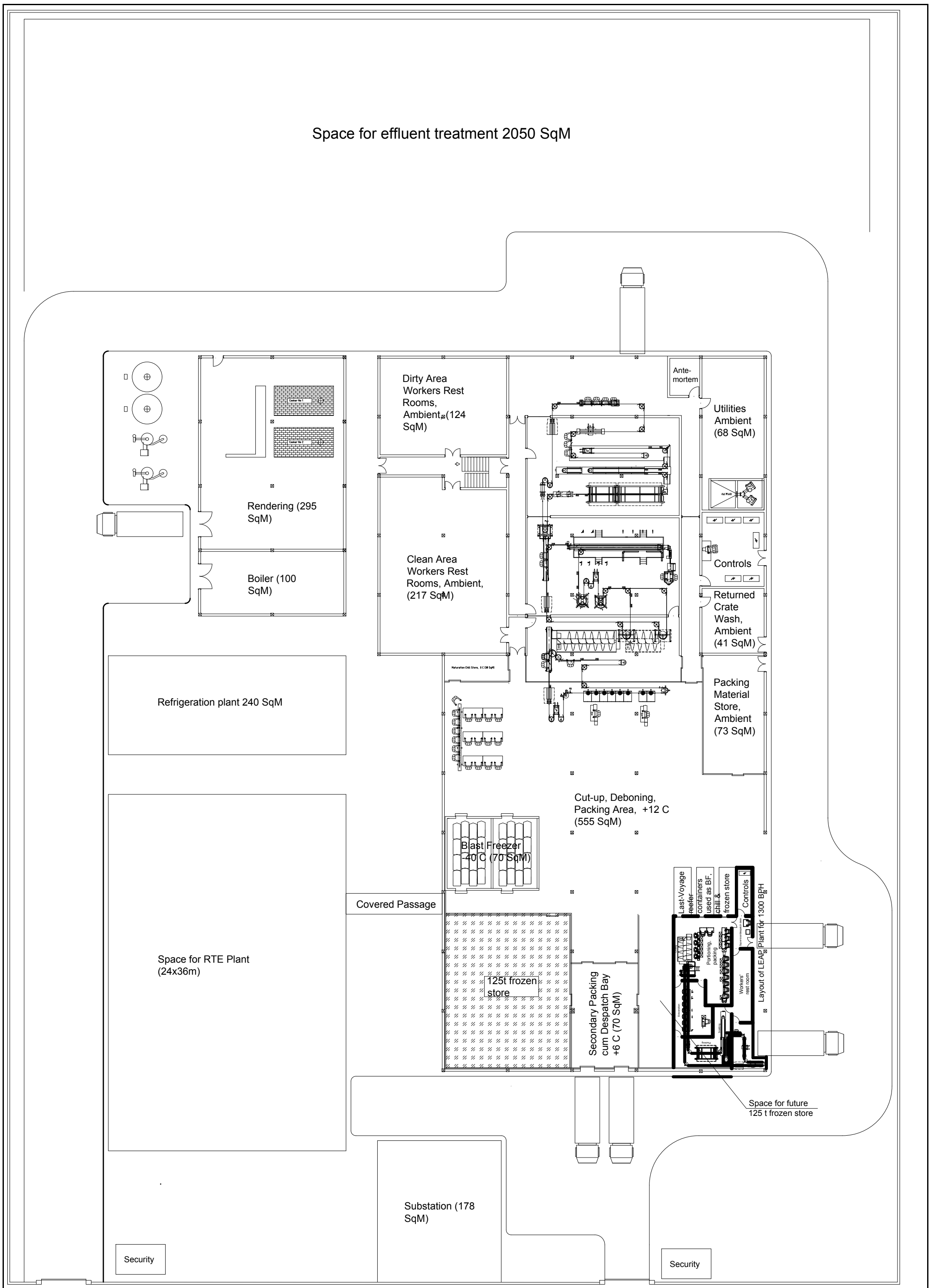


Figure 13 Plot plan showing the final 4000 BPH plant layout which figure 12 machinery will be upgraded into. Within the truss roof area of this layout you can see the initial 1300 BPH capacity layout. This drawing should give you an idea how much civil construction can be postponed to phase 2 if you begin with 1300 BPH LEAP layout.

2.2 Making A Simple Plot Plan

Let us choose a target capacity of, say, 4000 BPH for the allocated piece of land. First we prepare a layout for a 4000 BPH plant together with all the features that must be present. Such a plot plan is shown in figure 13. All the utilities, offsites and service features will be as shown, although the buildings and structures related to them, may, at the outset, be only sufficiently large to cater to the immediate needs of the process area shown in figure 12.

But if your initial process building resembles figure 13, you will be locking up a lot of funds in the process building to make it suitable for expansion to 4000 BPH, although much of that investment will remain unused and generate no revenue throughout the period that you run at the initial 1300 BPH capacity.

The LEAP approach overcomes this problem. Here is how we go about it. We select a small area on the edge of the future truss roof area of that 4000 BPH plinth layout for construction of a temporary processing area.

Within that area we place the layout of figure 12. Against this we place three last-voyage reefer containers as shown. One of these serves to freeze chicken carcasses and parts and the other two serve as chill store and frozen store respectively. You can persuade your plant vendor to purchase three last-voyage reefers in working condition from the docks and ship his machinery in them. Since you own the containers, you do not have to return them to the shipping liner.

Under international shipping rules reefers are plugged into the three phase power line of the ship to keep the built-in refrigeration system working and the contents frozen during transit. Such reefers have a sufficiently short marine service-life, which is rated in terms of hours of service and gross voyage distance logged. On reaching the end of their legally specified service-life they are discarded and sold as scrap. To ensure that fresh produce transported by reefers do not perish during their service life, they are designed and fabricated for endurance in difficult environments and have plenty of useful life left in them even when they reach the statutory limits of marine usage.

After laying your hands on them you can engage a maintenance firm from your nearest sea-port in a service and maintenance contract and for initial modification of one of them to perform as a chill store and another to perform as a blast freezer. All you then need is a three phase electrical connection. In this way you can do away with the need to invest in a refrigeration plant, save for procuring a water chiller of sufficient capacity for the screw chiller.

The walls of the LEAP process building are made of sandwich panels glued to the floor and held together by their built-in cam-locks. These panels can therefore be moved and re-installed where you need them later in the 4000 BPH layout. The roof and false ceiling of the design are similar to the final roof and false ceiling of the 4000 BPH layout and with some imagination you can design them in such a way that they integrate seamlessly and without the need of modification into the final roof and false ceiling design of the final building.

We now ask ourselves, have we followed the rules of a good design philosophy? Not quite. We have flouted some rules. In making the 1300 BPH plan ultra-compact, we have made the process flow semi-circular instead of making it linear. Notice how the process flow goes clockwise from arrival and hanging, through stunning and bleeding to evisceration and chilling and down to the portioning and packing section which is located rather close to the starting point. But careful positioning of the door connecting the scalding-defeathering hall to the workers' rest area rather than allowing it to complete the circle reduces the risk. Next, we have packed machines rather tightly together, but this is permitted here because this layout is not designed for expandability *in-situ*. This said, you are now free to evaluate if we did bend any more of the stated rules for the LEAP design and feel justified in so doing.

3 Construction Methods

Two distinct construction styles are popular internationally. The choice should depend on relative cost, functionality, safety and presence of an environment for method and skills conducive to this style of construction. Our use of the phrase environment covers skillset of local construction team, their access to specialised machinery and equipment for doing the job correctly, local availability of materials and local by-laws. The safety aspect is covered in another chapter - Design of Poultry Slaughterhouse - Materials & Safety. Here we concentrate on the remaining factors.

3.1 Identify Construction Blocks In A Slaughterhouse Layout

Before we pursue complex slaughterhouse designs, we need to understand construction methods, because they seriously impact your design. We first introduced these terms in section 2.1. Here we re-examine them as construction entities. First we need to recognise that, stripped of all superficialities, the typical poultry slaughterhouse is made up of two distinct construction blocks. We have referred to these two as '**Inflexible Block'** and '**Extrudable Block'**; terms which we coined to illustrate this fact. Look at figures 33 and 34 where the final 6000 BPH capacity layout identifies them.

As the capacity of a plant grows you need more space in both these newly defined blocks. However, we prefer to design the **Inflexible Block** with the maximum dimensions consistent with the peak capacity that the plot of land can support, assuming that eventually the company will put together enough funds to achieve this maximum. It does not matter if at the present moment the entrepreneur vows never to expand his plant capacity. He will change his mind when his business shows off its paces.

How does the Extrudable Bock expand? In this case, we design it in such a way that the area can be increased without taking a shut-down. We discuss these blocks in some detail here.

3.1.1 Inflexible Block

Within a process building lies a sufficiently wide Inflexible Block which houses live bird arrival, killing, defeathering, evisceration and screw chilling and all related service and utility spaces and structures on either side of them. So within this block we always design for the peak capacity. We leave enough space to accommodate all the machines that will be required at that stage and design a passage through which additional machines can be dragged in and properly oriented once they have reached their destination. Also we provide enough space on the sides of the row of process halls to accommodate all the workers' rest rooms, and utility spaces suitable for this peak capacity. This establishes the width of the Inflexible Block and allows you to choose an appropriate grid to fit it in.

The preferred construction style for the Inflexible Block consists of a reinforced cement concrete (RCC) frame building with non-load bearing brick walls and an RCC in-situ cast roof.

What measures does one adopt to determine and allocate space for inclusion of additional machinery in the Inflexible Block? Look at figure 33. Space exists in the live bird hanging area to accommodate more workers- given the staircases, it is even possible to use a part of it for that purpose. A second tentative row of scalder is shown beside the bleeding trough and additional bleeding length has been shown in figure 35 – version where expanded arrangement is shown. Space exists at the end of the row of screw chillers to accommodate another 9 metre long section. Likewise space exists in the row of drop stations in the weighing-dripping line to accommodate more drop stations and increase dripping length in the screw chiller hall. Most of these future changes have been shown with dotted lines in the original drawing, but in this small representation these differences do not show.

We will take some more examples to illustrate this point. Look at figures 33 and 35 and note the changes made possible because adequate space has been left to allow expansion without disrupting existing equipment. When such expansions are done, downtime is minimised to a couple of consecutive week-ends plus possibly one or two days of operational shut-down. On the other hand, if thought had not been given to expandability, downtime would be much longer.

3.1.2 Extrudable Block

In any layout, beyond the screw chiller, lies an Extrudable Block which houses portioning & packing, freezing and chilling spaces and service rooms comprising returned crate wash cum store and packing material store. As in the case of the Inflexible Block, design of this one also requires available space to increase as the capacity grows. But unlike the Inflexible Block, here we are able to add to the building by a process of **extrusion**.

The construction style chosen for the Extrudable Block makes use entirely of polyurethane sandwich panels for walls and ceilings with a truss mounted steel sheet roofing. Let us examine how this block is extruded.

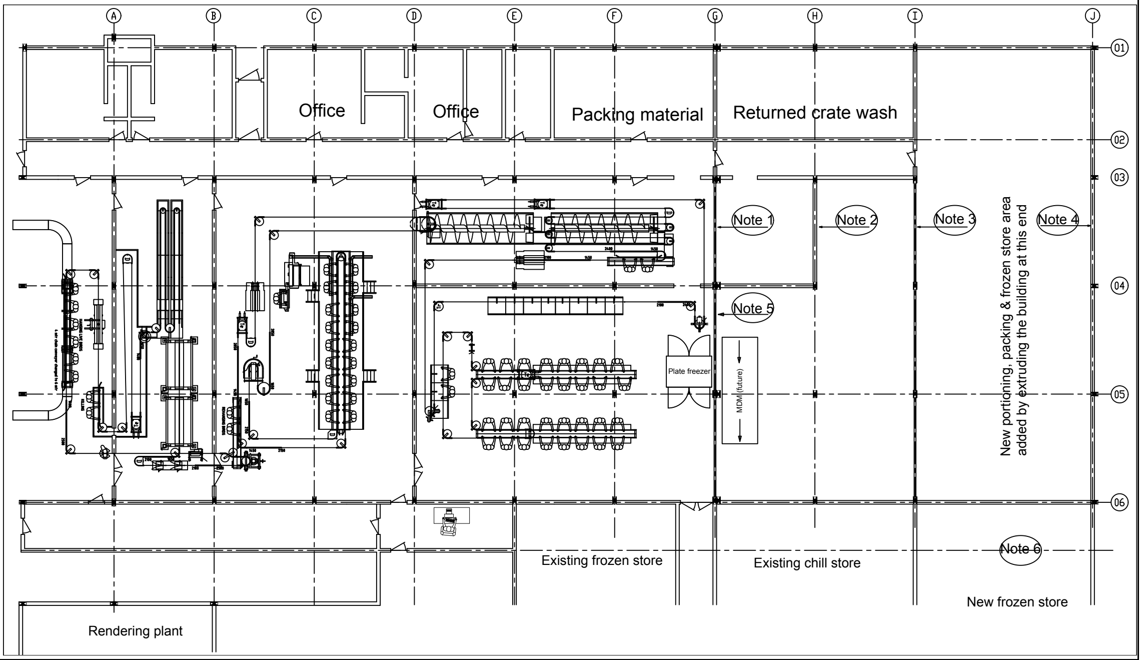


Figure 14 How extruding part of the building helps you implement expansion. Note 1, 4 & 5 indicates cam-lock panel walls that can be relocated to expand the enclosed spaces. Note 2 indicates repositioned cam-lock panel consistent with this expansion while Note 3 indicates the next alignment it will be relocated to. Note 6 shows how a new frozen store has been created consistent with this stage of expansion.

Read notes 1 through 6 in figure 14 and you will understand how the extrusion process works and what measures you must plan at the outset to make extrusion possible. This kind of layout allows expansion of hall space at some future date at the distal end of the building. For instance, in this example, by adding grid line J and extending the building up to it, the hall in this figure extends right of gridline G. Notes 1 and 2 show the wall positions separating the screw chiller cum dripping hall from the portioning & packing hall. Initially the right wall of the screw chiller hall was of cam-lock sandwich panel and the extent of the portioning & packing hall was gridline G. For expanding the plant **even while it continued operating**, the wall at gridline H and the brick wall marked by Note 2 were built. When the panels at gridline G were removed, you immediately had an expanded screw chiller hall and an expanded portioning & packing hall.

This expansion also called for additional frozen storage. In this case while the plant continued operating in the normal way, the final brick wall at gridline J was constructed and on that alignment an additional frozen store was built and an insulating inner layer added. Now both frozen stores and fresh chill store connect at the common despatch bay, which is not shown in this illustration.

Beyond gridline G (where the line of double columns denotes a thermal expansion joint) the building is normally designed with truss and sheet metal roofing. Since this kind of structure is light, it is normally necessary to have half the number of columns as one would in case of an RCC slab roof. But here, for some reason the entire plant roof up to gridline I was initially of RCC cast slab. Note that the distance between grid lines I and J is double that between any two previous gridlines because for this extension the lighter roof and the span was chosen and so the distance could be doubled. Halving the number of columns in such areas reduces the construction cost even as it reduces thermal ingress from the outside through columns. Note also that the frozen stores and blast freezers do not contain columns as being -20°C and -40°C respectively, columns would cause heavy ingress of heat load from the outside.

All this seamless expansion was possible because in this example sufficient space had been earmarked at the commencement of construction at the site. While we are on the subject, it is instructive to note that in this plant adequate width had not been determined for the Inflexible Block. This is the reason why there is a clutter at the hock cutter position and it seems impossible to add another plucker. Fortunately this problem could be overcome, if needed, by commandeering the corridor between the killing defeathering area and the rendering building. Note also that the full expanded length of the screw chiller is normally aligned at right angles to how it appears in figure 14. This is also a result of a bad choice of Inflexible Block width at the outset.

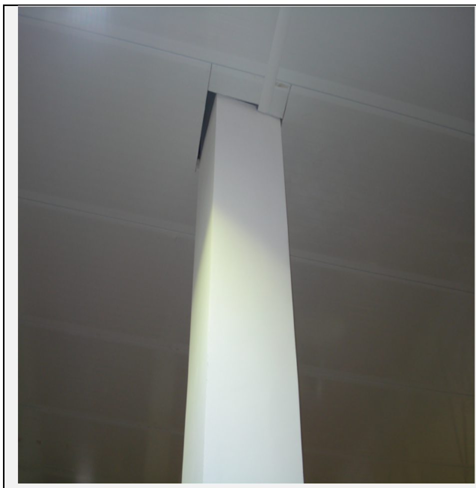
3.2 Construction Of Buildings In A Poultry Slaughterhouse

3.2.1 Brick Wall & RCC Slab Roof Construction

RCC slab roof construction follows two styles – with removable sheet scaffolding (whether of purpose-fabricated steel shuttering plates or shuttering plywood) and fixed scaffolding using a decking steel plate. For practical reasons each deck plate representing a floor must additionally be provided with an RCC floor topped with tiles or some other form of final flooring grade. So here a given thickness of reinforced concrete slab is poured onto the steel deck to form a composite roof slab.

The former method is typical for single-storey structures such as those under discussion here. The latter was developed for use in conjunction with steel frame buildings, which are generally commercial or residential in nature and are generally built in limited spaces in city blocks. They are built top-down as opposed to the former which are built bottom-up. Here it is instructive to learn the purpose why steel frame buildings were developed – by doing that we will discover how inappropriate their adoption would be for essentially single storey slaughterhouses.

Construction of multistorey buildings in city blocks requires access to sufficient stockyard area where steel rebars, cement, sand, stone chips and other building materials may be stockpiled close at hand. Where such a space is not available, it pays to first construct a steel frame and start building top-down by first laying a decking at the top and working one's way down. This gives you plenty of space on the ground within the confines of the steel framework of the building. In this way at each deck the stockyard remains easily accessible.



On June 3, 2013 a massive fire completely gutted the *Jilin Baoyuanfeng* poultry slaughterhouse in China, causing the death of 121 persons. Aptec researched the event and posted an article on its website pointing out the inherent hazards of designing the entire plant with sandwich panels. Similarly, in mid 2021, a plant under construction at Dharapuram, Tamil Nadu, was gutted for committing the same mistake. Fortunately the Indian plant was under construction at that time and no lives were lost. Safety features or the absence of them in relation to such construction form parts of the chapter titled Design of Poultry Slaughterhouse - Materials & Safety.

Figure 15 Picture on the left shows a common alignment problem with sandwich panel construction. Presumably the gaps will be caulked with in-situ PU foam. But that will not make it vermin proof! In this project a highly experienced French contractor was using inexperienced Sri Lankan workers to execute the building construction. The workmanship reflects not upon the skill and experience of the French contractor but the inexperience of the Sri Lankan workers.

Now we have two structural components forming the roof slab (or floor, by turn) – the steel decking which started out as a scaffolding and the RCC slab itself. And the composite structure must bear the live load placed on it. The strength of the floor is derived from both of them and suitable thicknesses are prescribed for the purpose.

Except for providing a smooth bottom surface to the roof slab, such steel decking cum RCC slab cast roofs impart no benefit to a poultry slaughterhouse, which is essentially a single storey building. For the slaughterhouse building, neither is a composite roof slab needed nor are we faced with a paucity of warehousing space. In addition, if you examine Aptec's design of embedded ceiling anchors for supporting the steel superstructure within the Inflexible Block, you will readily understand that they will not function in conjunction with steel decking roof slabs.

3.2.2 Sandwich Panel Construction

This appears to be the preferred design for all factory buildings and often for many civic utility and service buildings such as meeting places and wedding halls nowadays – more so in the West. Construction is rapid and such buildings look elegant although they lend themselves poorly to creative architecture, being, of necessity cubical in shape owing to the inflexibility of the building block – plain flat sandwich panels.

In this style the entire slaughterhouse area is built with PUR/PIR sandwich panels around a steel frame and roof as described above. We will call this the **Panel Building** style. An example of such a slaughterhouse building occurs in figure 28 and its cross section is shown in figure 29.

In table 16 we summarize the salient features of construction styles in use and compare their relative merits. You will discover for yourself as we proceed that the best course of action when designing a poultry slaughterhouse is to combine both of these styles in such a way as to achieve a balance between the thermal properties of sandwich panel buildings and sturdy, load bearing qualities of RCC roof slab in combination with brick walls as standard for construction of poultry slaughterhouses in India. Aptec has compiled a set of specifications which is available in table 18.

<table>
<tr><th colspan="3">Table 16 Summary of Features - Performances And Properties</th></tr>
<tr><th>Feature</th><th>Hybrid Building Style</th><th>Sandwich Panel Building Style</th></tr>
<tr><td>Cost</td><td colspan="2">Cost data can be examined and compared for these alternatives for specific functional sections from AptecApp and drawings that you may download from the Aptec website. In India at present panel buildings cost more per SqM than brick wall RCC frame and RCC slab buildings do. This is probably because of the easy availability of skilled workers for the latter.</td></tr>
<tr><td>Speed of construction</td><td colspan="2">Panel buildings can go up more rapidly provided plans do not change during construction and appropriate equipment is available for it.</td></tr>
<tr><td>Planning, standardization</td><td>Very difficult to standardize across construction jobs. Difficult to sell turnkey design service for an Indian construction contract from a central overseas head office.</td><td>One can standardize across construction jobs. Easy to sell design service from a central overseas head office.</td></tr>
<tr><td>Columns</td><td>Because RCC roof slab is heavy, you need a close grid of columns (typically RCC) in the 6x5 to 8x7 metres ballpark.</td><td>Because sheet steel roof is light, you can manage with fewer columns and because you lay a false (drop) ceiling, you can run piping etc on top of it, well hidden from view.</td></tr>
<tr><td>Precipitation proofing</td><td>Meticulous attention and additional features needed to prevent leakage. This kind of roof is unacceptable in areas with heavy snowfall.</td><td>Slope of roof can be increased to adjust for heavy precipitation. Even so, for heavy snowfall areas, additional strength in trusses is required. Leakage does not normally occur.</td></tr>
<tr><td>Skillset of builders</td><td colspan="2" rowspan="2">Abundance of brick & mortar construction skillset and lack of access to special equipment is the situation in the third world although a large part of this craftsmen community is stationed in the Middle East. The western world has a paucity of these skillsets today. This makes brick & RCC structures easy, cost effective & reliable in the developing world and the opposite true in the developed world.</td></tr>
<tr><td>Access to special equipment</td></tr>
<tr><td>Life of building</td><td>Thirty years for whole building</td><td>10-12 years for panels. 30 years for steel frame</td></tr>
<tr><td>Fire safety</td><td>High</td><td>Low</td></tr>
<tr><td>Working space & suspension of superstructure</td><td>Working space is somewhat restricted because of relatively close grid of columns. The rigid roof slab allows suspension of steel superstructure and mounting of flake ice maker over the screw chiller for direct feed.</td><td>Working space remains restricted in killing to chilling areas because of need for floor-mounted steel superstructure supports. There is much less restriction in portioning, deboning, packing area. You need to build a separate platform for mounting the flake ice maker, or as in the case of some badly designed plants in India, flake ice was made and stored in a separate room and had to be manually fed into the screw chiller.</td></tr>
<tr><td>Vermin proofing</td><td>Very high.</td><td>Poor in areas with low skillset and absence of appropriate construction equipment.</td></tr>
<tr><td>Design flexibility</td><td>Good;</td><td>Poor. Because the architect is restricted to the use of a cubic structure or a square building paradigm</td></tr>
<tr><td>Expandability</td><td colspan="2">Allows no expandability in the Inflexible Block, hence they must be designed ab-initio for final capacity. Full expandability of portioning onwards is retained in the cold areas by simply extruding the truss structure for roof and adding roofing sheets.</td></tr>
</table>

3.2.3 Hybrid Construction

The preferred design involves a combination of brick walls and RCC roof slab for the plant for the Inflexible Block and use of truss roof with sandwich panel construction in subsequent departments (Extrudable Block). This is the **hybrid construction style**. It restricts the use of sandwich panels to areas where their thermal properties are required, thus reducing fire hazard and vermin access to the extent possible and additionally provides a sturdy roof slab to mount flake ice makers on and suspension of the overhead steel superstructure for the overhead track. Table 16 lists the benefits and suitability of each building style and shows how a hybrid construction style is most appropriate for India and most of the developing world.

3.3 Other Buildings

Two distinct plans and construction styles are in use for rendering and have been covered with examples in the chapter titled Rendering Design Evolution. These have been named **Design A** and **Design B** respectively in that Chapter. Their relative merits have been discussed and it has been conclusively shown that Design B is appropriate for a rendering plant captive to poultry processing. In Design B, this building is special, consisting of 2.5 or 3.5 floors and generally built for a large live load, therefore it must be of RCC frame, brick walls and RCC floor slabs[13]. Design A, on the other hand, consists of a large single storey shed with undifferentiated internal floor space. Aptec does not approve of Design A which, nevertheless, continues to be promoted by some vendors[14].

Instead of discussing the other utility and service buildings which form part of the plot plan separately, we cover them collectively here in table 17.

Table 17 Preferred Construction Styles And Location Of Offsites & Utility Buildings

Building/construction	**Type**	**Preferred Location**
Central refrigeration	RCC or steel columns with sheet steel roof, brick/prefab cement concrete panel walls, louvres for natural ventilation, structure and rails of EOT crane for maintenance.	Adjacent to, but separated from the main process building for fire tender entry. Building is connected by gantry for pipelines and for maintenance thereof.
Electrical sub station	According to local by-laws.	Adjacent to HT line entry into the premises. Minimise distance to central refrigeration plant to minimise LT cable length.
Effluent treatment plant	According to the vendor's specs.	Preferably at the back of the premises.

3.4 Aptec's Recommended Construction Specifications

	Arrival, lairage, hanging area	Defeathering, EV., spin chilling	Packing & portioning	Secondary packing, ante room, despatch bay	Blast or spiral freezer, chill & frozen store	Laboratory	Workers' rest room, canteen	Offal pit, air compressor, vacuum system	Rendering, offal slurry filtration	Central refrigeration plant room	Elect. sub-station, DG sets, panels	Effluent treatment control area	Raw water treatment area
Walls (RCC column, brick wall)		√				√	√	√	√		√		
Walls (RCC column, GI roof sheeting over brick wall)										√		√	
Walls (PU sandwich panels with outer weather protection)			√	√	√								
Walls (glazed tiles up to minimum 1850 mm as per USDA)		√				√	√	√	√				

Walls (if brickwork, enamel paint up to ceiling)		√				√							
Wall Openings (glazed tiles, sill slopes towards dirtier area)	√	√	√						√				
Roof (RCC slab cast on column-beams frame)		√				√		√	Ask		√		
Roof (GI sheet over steel column-truss frame)	√		√	√	√					√		√	√
Ceiling (thermal insulation false ceiling)			√	√	√								
Ceiling (if RCC slab roof, enamel painted)		√				√							
Ceiling load (unless RCC slab roof, add floor mounted load bearing columns)				For AHU only									
Floor (dewatered granolithic)					√								
Floor (skid-proof natural stone or vitreous tiles)		√	√	√		√		√		√			√
Floor (thermal insulation, anti frost-heave, anti-skid)					√								
Floor (thermal insulation)				√									
Floor (floor-gutters with dip-galvanized cover grill)@@	√	√	√										
Floor (foot-bath, handwash sink at entry-points)		√	√										
Door (washable, if glazed use shatterproof glazing)	√	√											
Door (insulated, washable, if glazed use shatterproof glazing)			√	√									
Door (all docks with leveller & dock-shelter; for all else use insulated door)					√								
Door (emergency exit, with bilingual illuminated signage on fail-safe power supply)			√	√					√	√	√		
Door (opens outwards)			√						√	√	√		
Door (any other appropriate type)	√					√	√	√	√	√	√	√	
Window (sill inclined towards floor of dirtier area)		√	√										
Window (with double glazing)			√										
Window (PVC, steel or aluminium; if glazed, use shatterproof glazing)		√	√										
Window (with flyscreen, no glazing)									√	√	√		
Height (RCC areas, min 4500mm FFL to beam-bottom)		√											
Height (Truss roof areas, minimum 6000mm FFL to truss-bottom)			√	√	√					√			
Height (Truss roof areas, min 8000 mm from road level to roof ridge)	√												
Lighting (both architectural & technical, shatterproof fixtures)		√	√	√	√								
Lighting (technical, blue, low level of illumination)	√												
Forced ventilation (see Chapter on Engineered Ventilation for Biosecurity & Efficiency)	√		√	√					√	√			
Notes:													

Plinth level for all areas in the main process building including both Inflexible Block and Extrudable Block is +1200mm above internal road level. All foundations are of RCC

Temperature for all areas ambient except: portioning & packing areas +12^{o}C, chill store -1 to +4^{o}C; frozen store -18^{o}C, blast freezer -40^{o}C, despatch bay +8^{o}C

Ask = consult concerned vendor(s)

@@ = Floor-gutters are of 300 and 600mm width, Indian patent stone hand-trowel finished, with semi-circular bottom.. Flat-bottomed floor-gutters are inefficient. Where skill with hand trowel is unavailable, consider using longitudinally split Hume or RCC spun pipes.

Table 18 Showing Aptec's recommended specifications for all buildings in a poultry slaughterhouse

Aptec recommends the following specifications for poultry slaughterhouses in tropical climates. These are several factors that relate not only to the material or manner of construction, but to local factors like skillset, speed of construction, cost and so on, which have already been compared in table 16.

4 Other Design Factors

4.1 Are You Locating In Industrial Estate or Greenfield?

We have covered this topic in the chapter on Design of Poultry Slaughterhouse – Land & Location[15]. The discussion calls for a different approach to planning if your client has already purchased a piece of land in an industrial estate. In India agencies offering space within industrial estates have no idea of the needs of a poultry slaughterhouse – they continue to offer pieces of land which are woefully small for this industry. In this respect they remain real estate companies in spirit – not agencies responsible for promoting industrial growth. You are advised to read the chapter to familiarise yourself with the arguments we make in favour of greenfield properties for poultry slaughterhouses.

4.2 Must You Combine The Entire Process Under One Roof?

We have covered this topic in detail in the chapter on Design of Poultry Slaughterhouse – Land & Location[16]. In it we propose that because most of central and peninsular India is water-stressed, it is very difficult to identify suitable plant sites. As project consultants we at Aptec have always considered this the most difficult task for a new poultry processing venture. To partially overcome this problem, we broke up the plant into parts based on the water requirement and need for heavy investment in power, waste-water treatment and refrigeration and came up with the **Hub and Spoke Concept.**

Under this concept we propose a limited number of large capacity processing **Hub** plants located in the hinterland, away from dense habitation, close to water source and on cheaper land. Scale economies operate strongly in the Hub plants because the bulk of the investment in slaughterhouses goes into the Hub.

From such Hubs fresh chilled carcasses can be transported over distances of up to 150-200 kilometres to urban consumption centres where **Spoke** facilities may be located. Spoke operation employs large number of manpower, which would be readily available near towns and cities, needs very little power, refrigeration and water and produces no liquid effluents. Since the large labour base is resident nearby, it can use urban mass transit system for commuting and the plant management then has to cater neither to their commute nor their housing.

In addition because Spokes will be located close to the consumer, this arrangement will be better able to manage product mix, reduce inventory and piggyback onto the mushrooming home-delivery industry outfits for distribution of its product. Also, with such an arrangement, while bulk deliveries of fresh chilled carcasses are in reefers in transit on the highway, the carcasses they carry will mature during transit and by the time they reach the Spoke plant, they will be ready to be portioned and deboned or stored in the chill store.

Meanwhile Hubs can continue to make bulk shipments directly to their bulk buyers.

4.3 Does Your Design Cater For Plant Visitors?

From time to time your plant will have visitors – customers, school and college students and others. If you build a viewing gallery, not all of them need to enter the work-area and disturb the workers. Furthermore management personnel need to routinely monitor the work without disturbing the workers. This is another instance where a viewing gallery may serve them well. By constructing it, you will also reduce operating cost as you will not need to use disposable biosecurity apparel such as overalls, face masks and hairnets for every visit by every visitor.

For a viewing gallery to function you need exactly the right heights. Too high and the internal height of the RCC slab building will need to be raised, which in turn will raise construction cost. Insufficiently high and you will create difficulty for cross-traffic below the gallery. A section with the best height for the gallery is shown in figure 19. In figures 30 and 33 you can see the viewing gallery over the Inflexible Block and extended into the Extrudable Block. And in figure 32 you can see its cross section within the Extrudable Block.

4.4 Will You Award Construction Contract On Turnkey Basis?

The turnkey design firm you wish to hire may be local or foreign. If it is foreign it will tend to use standard construction materials and methods rather than leverage the use of local materials to cut costs. Moreover, the majority of foreign turnkey engineering companies operate in many countries and it is difficult for them to have information on local materials or maintain a large battery of local collaborators who do have such information and experience working with local materials. As a result turnkey designs made by foreign engineering companies will invariably be 100% sandwich panel buildings with dip-galvanised steel structural framework bolted together at site.

Alternatively if the foreign turnkey designer does have a local engineering and construction collaborator, then the design gets the best of both design approaches. To this end Aptec has a working arrangement with Le Bat of Malaysia and Orkay Constech India Private Limited of India with whose participation the best of both approaches is available under comprehensive technical consultancy from Aptec.

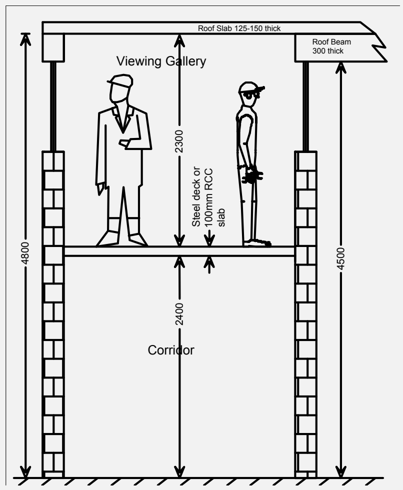


Figure 19 Section through an appropriately sized viewing gallery

4.5 Do Your Designs Qualify You As An Egyptian Embalmer?

Many machines that make up the poultry slaughtering process are evolving, and existing ones may be replaced from time to time with others of better and more efficient design. Or maybe one of your machines fails and needs replacement. Finally, machines need regular maintenance which requires access space around them. For all these reasons layouts cannot pack machines tightly, leaving inadequate space for repair, maintenance, removal or replacement of machines. Therefore plant design must always incorporate sufficient space around machines.

Unlike the increasingly popular design trend incorporating built-in obsolescence, so characteristic of materialistic consumerism, plants are expected to last long and lend themselves to modification and expansion over their lifetime, which may stretch over several decades. A plant is not a consumer appliance like a mobile phone. You do not trade it in for the next model every three years.

In a brick and mortar design, a building of appropriate dimensions is constructed, finished and then individual machines are dragged into position and joined together with an overhead conveyor system. For this purpose corridors are required, through which machines may be brought in. Also these same corridors provide the means to remove obsolete machines for replacement. By careful consideration these same corridor spaces may also serve as routes for entry and exit of workers and for emergency evacuation.

However, with sandwich panels construction, a different design approach is frequently adopted. First the floor is constructed. Then the machines are installed and hooked up. Finally sandwich panels are cut to required dimensions and erected around the whole – **sarcophagus style**. It is like placing the foil wrapping over a piece of candy after it gets formed. Such an approach assumes that an industrial plant is just another Egyptian mummy that will exhibit no change for all time to come. The building therefore serves an arrangement of machines no better than a sarcophagus serves a mummy.

Figure 20 A **sarcophagus**, typically an Egyptian box-like funeral receptacle for a corpse or mummy, commonly carved in stone. It is usually a close fit around a mummified corpse, after the fact that the mummified state is permanent, and allows no movement.

Recently this author was proudly shown the layout drawing of a large plant built in North Vietnam for bulk supply of whole chicken carcasses to southern China, and asked to comment on its qualities. This layout drawing was made by one of the three leading poultry processing machinery suppliers worldwide. It was an extremely tight layout based on panel construction with a single mid-line row of prefab steel box columns. The functional departments had hardly half a metre of aisles width for movement of personnel. I could do no better than to reply that the designer surely possessed all the qualities of a budding Egyptian embalmer of mummies!

I pointed out the difficulty of replacing one of the several automatic machines should it experience a catastrophic and irreparable damage. In such a situation you would have to uproot dozens of adjacent sandwich panel walls, dismantle scores of tracks and shift several machines out of the way and later refit them. All this would call for days, if not weeks of shutdown. Instead, had the draftsman left aisles of open space in each department, such an eventuality could be met easily. And the resulting small increase in capital cost would have gone practically un-noticed. With some intelligence the vendor's sales team might have turned this to their advantage by pointing out the relative merit of leaving enough aisle width in their layout.

All major plant vendors relegate their plant layout function to draftsmen within their sales-support design team. These are typically greenhorns who may be skilled at computer-aided drafting (typically AutoCAD), but unfamiliar with the business of slaughtering poultry and inexperienced in plant design. Also because such draftsmen typically concentrate on producing least-cost layouts to boost sales, they minimize track lengths and so the machines get packed tightly together. Finally most salesmen and draftsmen lack the wisdom of permitting an increase in capital cost to reduce operating costs. In actual fact capital cost is easier to budget for and manage, but persistently high or negative operating revenue, such as that due to frequent breakdowns and long shut-downs can have irreversible and uncontrollable outcomes for a business.

We will now examine two cases of mummy embalmers at work.

Sarcophagus 1 Figure 21 shows the layout designed by a vendor's young Autocad expert for an Indian customer's 4000/8000 BPH slaughterhouse. In this particular instance the customer had already cast column footings according to this layout before this author was retained as a consultant and had an opportunity to visit the site, check the activity and correct the errors.

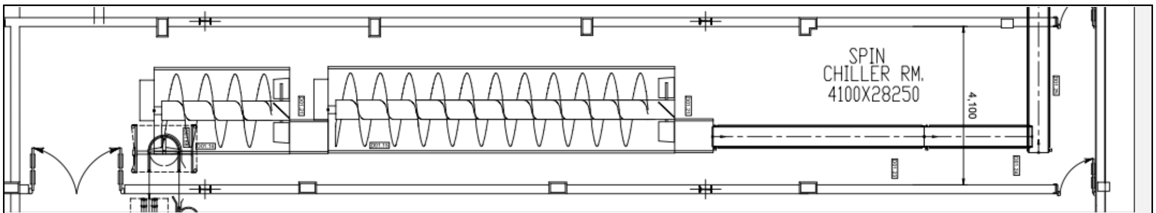


Figure 21 Vendor drawn layout supplied to a customer for placement of screw chillers of 2100 diameter and 3500 + 9000 lengths inside their 4100 wide **"sarcophagus-style"** hall formed by 250mm brick walls.

With this layout, on expansion, you would be expected to increase the second chiller to a length of 18000 by joining a section of 9000 or two sections (of 3000 + 6000) to it. But considering how this screw chiller hall had been dimensioned, assuming that you could somehow get these sections into the hall through the 2500 wide door shown on the left bottom corner, how would you make them turn? And if you somehow managed to turn them, how would you make two chillers of 2100 width slide past each other in a 4100 wide hall?

In the first place, even for the initial capacity, how could you position two chillers of 3500 and 9000 lengths in the hall? Did the young designer expect the customer to first place the machines on the floor and then build the walls? Obviously this is what you get when inexperienced draftsmen plan slaughterhouses merely on the strength of their skills in AutoCAD. You may as well expect anyone familiar with the English alphabet to break out in a spontaneous recitation of Shakespearean sonnets!

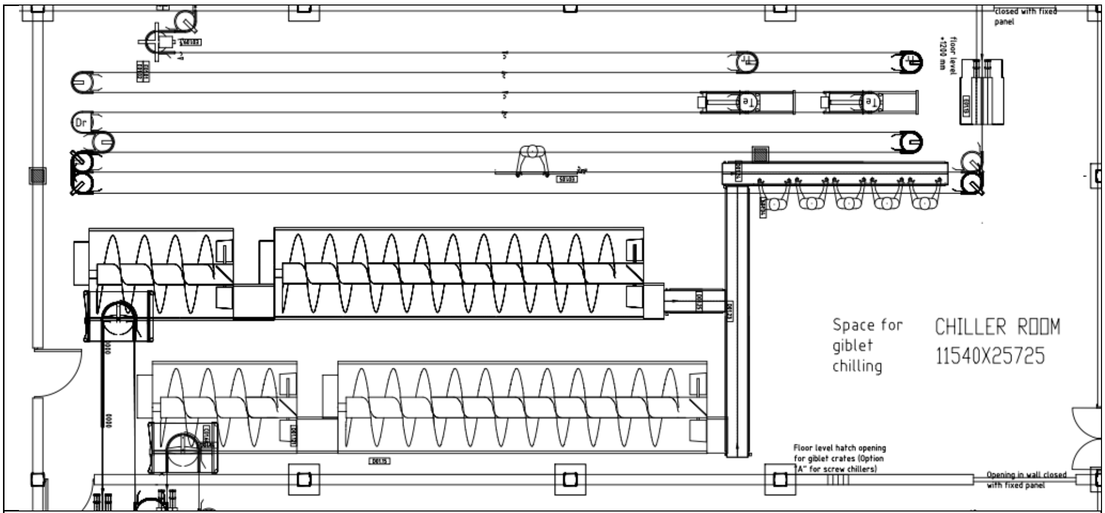


Figure 22 Here is the solution to the above incorrect layout of the screw chiller hall. Note that it now includes dripping space which had incorrectly been placed in the Extrudable Block and would have contributed to severe saturation of its interior. This layout also reserves space for future extension of screw chilling – with a superior method of two parallel screw chiller lines – the first to cater to the initial capacity and the second for doubling it. A 2500 opening on the bottom right is one of a series, placed in line and plugged with panels all the time. When new machinery needs to be brought in, the plug panels are dismantled and the machines dragged in. Note there is a similar panel plug at the right hand top – to allow dragging in of any large piece of machinery all the way in from the live bird hanging area.

Aptec solved the problem by redesigning the building using the odd grid spacing and column footings which had already been cast. We adapted and redrew the entire building to match the column positions, adding two extra grid lines and columns associated with them at the front end of the layout. This increased the building length by a bit, and the overall dimensions of the building also increased a bit, but it did result in a workable solution.

Sarcophagus 2

In figure 23 you can see an example of a tight layout which we modified into a workable alternative by simply adding two 2200 wide doors and widening the hall by 1150mm. These are doors A and B shown shaded in this drawing.

These simple modifications provide sufficient space for all ten large machines to be moved in or out or replaced when needed. By making these changes the overhead conveyor track length increased by a mere 2420 mm or less than half a percent of total equipment cost.

Manual operations are located at the top end of the hall which has two exit doors at opposite ends. Consider the single exit route into the automatic machine section. What would happen if maintenance workers were trapped in this section in the event of an emergency, when they would be required to navigate a complicated path around the machines to flee. Then further imagine what additional complications would ensue if the lights went out. Finally, note the absence of aisles and corridors in the original layout, that would make the replacement of any of these machines a nightmare, requiring major disruption of operation for several days.

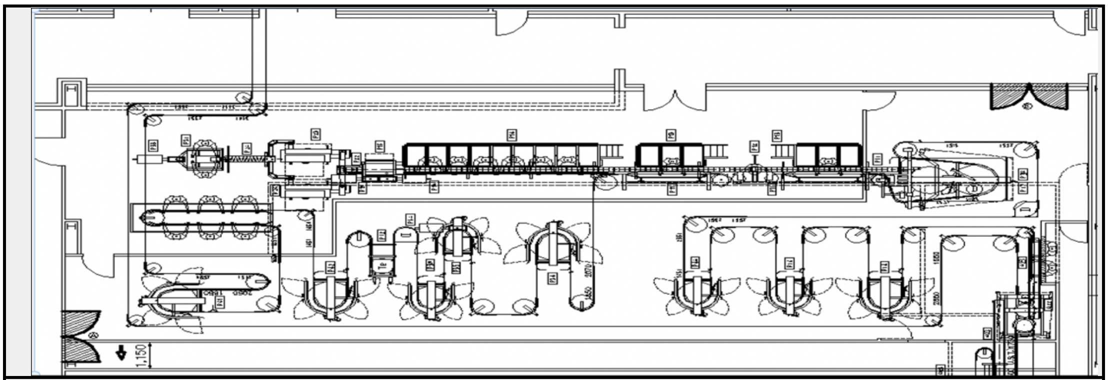


Figure 23 This drawing shows the evisceration department of a 12000 BPH plant set up somewhere in the UK. The 29.7x10.8m (321 SqM) hall houses 13 large machines (not counting the platforms for manual work), each of which was either brought into the space first and after that the sandwich panel walls were erected around the installed machines - sarcophagus style.

4.6 Does Your Design Cater For Frost Heave?

The earliest practical and economically significant instances of this phenomenon occurred when men laid pipelines for the transport of petroleum fuels through permafrost and freeze-prone terrain. Pipelines were of steel, supported off the ground over masonry pillars. Everything worked well when the weather was warm, but with the onset of freezing weather, the masonry supports experienced an upward lift and the pipe alignment went awry, resulting in damage to pipes and spilling of crude oil or leakage of gas. This is an example of frost heave.

Figure 24 Over-ground petroleum pipes laid over terrain prone to freezing in winter

What causes this? Small amounts of water in the soil under the supports freeze in the cold and since ice has a lower density than water (it expands by 9% upon freezing[17] which is why ice cubes float in your glass of drink), it expanded. Since the soil under the support had already been compacted for stability, this expansion forced the foundation upward and caused misalignment. Such a formation of pockets of ice in the foundation space under a man-made structure is referred to as an ice lens. Frost heave tends to occur mostly in moist, silty, thick, active soil layers, such as those that are common in discontinuous permafrost – the very wilderness through which these petroleum pipelines were laid.

4.6.1 Frost Heave in Slaughterhouses

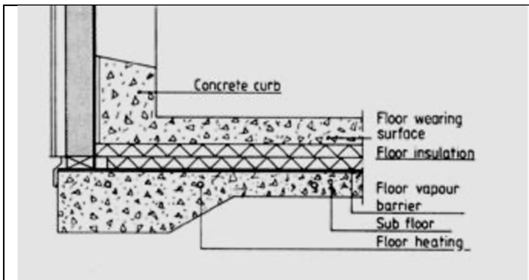


Figure 25 Construction of the buried sub-floor structure of your sub-zero floors[18]

But what does frost heave has to do with design of slaughterhouses? Plenty. Let us examine the facts. Slaughterhouses typically have large refrigerated floor areas under the portioning, deboning, packing, blast freezing and frozen stores - the very areas which we have called Extrudable Block. After the block is built, the ground under this section of the building never gets exposed to sunlight or air even as sub-zero plant spaces such as blast freezer chambers and frozen stores above the foundation are refrigerated down to well below freezing temperatures. Over time the soil under these areas tends to accumulate more moisture than other parts of the property, and that moisture freezes to form ice lenses.

To understand this better, let us examine the below-grade construction in these sub-zero temperature areas. In such cases the wearing floor is made of dewatered granolithic concrete. Below it is an insulation of polystyrene blocks and under it is a thin plastic sheet which acts as a vapour barrier. This barrier also prevents the exchange of liquid water between the ground and the frozen store.

The sub-zero temperature work-area draws heat from the product stored in it as well as from the six surfaces of the enclosure. Some heat enters through the wall and ceiling insulation and some enters through the floor insulation. Eventually through constant extraction of heat, ice lenses form within the sub floor as mentioned. These exert an upward compressive force which squeezes the floor insulation. With this constant squeezing, the polystyrene insulation becomes less and less effective and eventually the upward pressure causes the dewatered granolithic floor to develop micro cracks which eventually leads to fracture of the floor. And where some liquid water is available, it trickles down into the sub-floor through these micro cracks and increases the size of the ice lenses.

How should we define sub-zero temperature work areas? Obviously it should cover all work areas that are typically required to operate below 0ºC, -20ºC in frozen stores and -40ºC in blast freezers. Just to make sure that adjoining spaces do not experience frost heave, we should include roughly half a metre extra on all sides of such spaces.

4.6.2 Solutions To Frost Heave

Four solutions are possible. These are:

(a) **Permit natural ventilation** below the grade in frozen areas. Flow of air through the space between the floor of the frozen store or blast freezer and the ground will prevent the formation of a sub-grade ice lens.

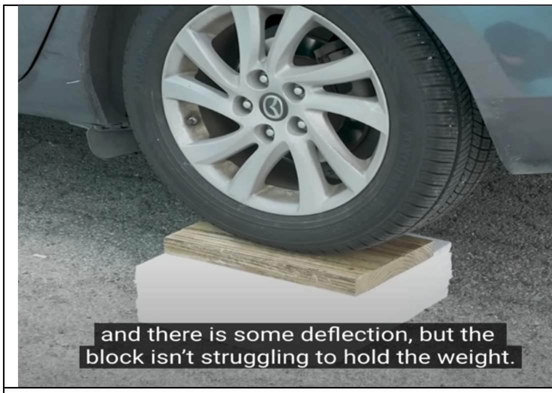


Figure 26 Showing the load bearing qualities of polystyrene foam block. This is the property, combined with its thermal barrier properties which makes it suitable as a floor insulation material. Even so, it can get compressed through persistent action of frost heave.

But there is a snag here. Consider the large thermal excursions that an aggregate floor slab comprising rebar reinforced concrete must experience with every freezing cycle in a blast freezing chamber were this method to be employed in a tropical setting. The inside surface would be taken down to -40ºC in each cycle and the outer surface taken up to +40ºC by ambient conditions. Surely, a thermal excursion of 80ºC across an aggregate structure 150-200mm thick could soon become the cause of a catastrophic failure. However, this method might work if the floor was a composite of steel decking and poured reinforced concrete.

(b) The second method is to **lay a grid of pipelines below the floor insulation layer and ensure a constant flow of ambient air through it**. This should keep the ground below the insulation from freezing and therefore prevent frost heave. Although the design of space below the frozen chamber may be complicated and it would not be easy to mathematically model the system owing to the large number of unknowns, one could over-design it sufficiently to get by. The pipeline grid can easily be a series of thin-walled PVC pipes laid within a lean concrete or PCC matrix and the ends of these pipes made accessible beyond the plinth. But there are complications to such a design.

Firstly the sub-zero temperature areas must be arranged within the building in such a way that the grid of pipes extending from one edge of the plinth to the other must at the same time adequately cover the areas susceptible to freezing and the size of such a grid must be minimised. We can say there ought to be a **sub-zero area contiguity as well as compactness.**

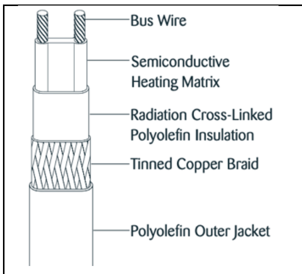
Secondly such pipes must be laid with care so that they slope down towards one of the plinth walls in order to get rid of any condensation that is sure to occur within.

Finally the openings at both ends must be fitted with SS gauzes to prevent vermin from entering and nesting within the pipes.

Can the flow of ambient air be regulated or enhanced in such a grid? Yes. There are several ways to do so. Combine the exhaust end of the pipes within a duct and raise a couple of chimneys from that duct, providing each chimney with a fan. Now the speed of the fans can be regulated by a set of temperature probes embedded within the PCC slab. Additionally, if you manage to suck out air via the intake ends from your refrigeration plant room, you will always have a free supply of warm air and this will improve performance.

(c) The third method uses **hot fluid heating with waste heat of the refrigeration system.** An ethylene glycol pipeline embedded within the sub-floor matrix would enable you to prevent frost heave. To implement such a system you will need to work closely with your refrigeration vendor at the design stage.

(d) The fourth method uses **electrical heating.** Here you lay a matrix of electrical heating cables specially designed for this purpose under the insulation layer. These cables require to be laid underground within a conduit. Several products are available in the market for this. Figure 27 shows one. These cables are designed to be cut and terminated to the required length under field conditions and each length thus becomes a heat tracing circuit along its entire length. The semiconductive heating matrix in this circuit provides a self-regulating feature so that energy consumption is roughly as required. In this way the system conserves electricity in two ways – by limiting the use of power to just enough to prevent formation of an ice-lens and by not adding to the eventual refrigeration load by pitting the refrigeration circuit against excess heat generated by the tracing.



Minimum surrounding temperature for installation -51^{o}C
Maximum operating temperature at power-on +65^{o}C
Max exposure temperature at power-off +85^{o}C
Circuit protection - 30mA external ground fault protection required
Bus wire – 18 AWG nickel coated copper
Metallic braid - 12 AWG copper

Figure 27 Features of a self-regulating anti-frost-heave element[19].

What can go wrong in such a system? Short circuit or earth faults can occur. When a short circuit or a short to earth occurs, the safety fuse mounted in the control panel will blow and the affected buried anti-frost-heave segment will no longer be available to you. Since it is not practical to tear open your floor and fix such a problem – you will be stuck with the effects of this malfunction for the remaining life of your facility. For this purpose it is useful to include some degree of redundancy in your design and include one earth fault controller per buried segment instead of mounting them in parallel.

For refrigeration areas built on a greenfield plot, consider an approximate height build-up of 600 mm comprising floor insulation, anti-frost-heave tubes or floor heaters, and suitable flooring.

4.7 Commuting Between Buildings

It is impossible to keep the internal roads free from dry and powdery bird droppings and feathers in a poultry slaughterhouse. Every time someone exits the process building and returns to it, he will have walked on the internal roads. Therefore, with every walk, that person picks up some dried bird droppings and feathers on his shoes and fine dust containing dried bird droppings on his person and clothing and brings it back into the process building. Foot baths help, but only to an extent. So unless you install air showers at every entry point, you cannot beat this problem. This problem is particularly troublesome for laboratory personnel because the contamination they bring in compromises the integrity of their activity. The normal job function of laboratory staff is to take frequent swab samples of surfaces throughout the slaughterhouse and culture the swab to check for bacterial activity. To do so the staff needs to make frequent trips between the laboratory and the rest of the slaughterhouse building throughout the day.

To facilitate this, it is easiest to ensure that from the time workers and laboratory staff check in, to the time they leave for the day, they be retained inside the process building. The laboratory staff are facilitated in their work by letting them use the viewing gallery to commute among all the processing departments. The task of preventing contamination of the laboratory by aerosols in the ambient air is adequately met by managing the air flow withing the plant as explained in the chapter on Design of Poultry Slaughterhouse - Engineered Ventilation for Biosecurity & Efficiency.

Unfortunately recent rules enunciated by the Indian authorities specify that the plant laboratory be located outside the main process building. Murphy's law will operate with a vengeance and this ruling will cause more biosecurity issues than it hopes to control. In our opinion this is a retrograde rule.

4.8 The Problem With Vendor Layout Drawings

What distinguishes a layout drawing made by a plant vendor from that made by a consultant? A plant vendor is not concerned about the specifics of your construction and operation as long as you follow his "example" or "concept" layout enclosed within the "example or concept" building outline he gives you. In fact he makes a layout drawing not for construction but to firm up dimensions and estimate the price of his offer. He may even be willing to offer some advice if you insist, but he will always takes pains to pronounce that he is not bound by it and that you should cross-check with experts.

Having read three chapters of this handbook, covering engineered ventilation for biosecurity & efficiency, safety in choice of construction materials and rules for making good plant layouts, you should have understood by now that designing a poultry slaughterhouse requires not just knowledge of process, science and machinery, and experience in the field, but also a good familiarity with local construction methods, materials and skills and principles of industrial designing. At present there are three main vendors of poultry processing plants worldwide and neither their representatives, nor even their draftsmen are proficient in all these fields. Some of their senior staff might be up to the task, but they are rarely involved in design for their customers. And even if they could make their services available, no developing world customer could afford their services. It is therefore not surprising that plant vendors are traditionally hesitant to talk of specifics outside their machines and the process.

But in recent years Aptec has noticed that in their race for dominating the growing Indian market, vendors have started providing some specifics in their layout drawings and that these specifics reflect a poor and incomplete understanding of the subject. Therefore unknown to them, such vendors may be causing more harm to their market ambitions than they realise. Why? By law a consultant is responsible for his advice and should it, followed faithfully, lead to financial loss to his client, he is liable under the law of Tort. It is true that with the lax justice delivery system in India, no customer is expected to legally challenge bad counsel given by such vendors, but it is likely that the cumulative effect of such bad counsel may result in eroded market share for that vendor over time.

Aptec's first professional experience in Pakistan, in 2006, concerned a small plant whose building had been constructed based entirely on a concept drawing. The concept drawing did not, inter alia, mention the clear FFL to ceiling heights in various departments. However, based on this concept drawing the customer appointed an architect and the building was constructed with a uniform internal height of a mere 2.75 metres because the architect was familiar only with residential buildings. What followed thereafter was a prolonged and bitter argument between Meyn and the customer. This author was then sent to Pakistan under orders from Meyn HO to try to sort the problem out. Indeed it did get solved, by the simple expedient of cutting up a 3x3m RCC roof slab, (where the height was too low for the machine), raising it up an additional metre with the help of hydraulic jacks and fixing it there on a new set of pillars and beams.

The problem would not have occurred in the first place if the concept drawing carried the instruction "Not fit for construction at site" or "Hire the services of an experienced consultant to interface with your architect", or if Meyn's local agent had a reasonable experience with industrial plants and took the trouble of advising his customer. Following the amicable solution mentioned above, this author was instructed by Meyn HO to visit Pakistan regularly and offer hand-holding to customers and education to the local agent. Visits continued till 2013, by which time it became too dangerous for an Indian national to visit Pakistan. Meanwhile this simple expedient of hand-holding made Meyn the dominant supplier in Pakistan, a status that it continues to enjoy a decade later[20].

Therefore for the benefit of vendors who have taken to providing specifics to Indian customers, the countless consultants that have sprung up all over India and in the overall interest of the industry which Aptec has served for nearly three decades, we decided to write this Handbook and make it available in the public domain. We believe that if vendors are able to provide competent technical hand-holding from experienced consultants, they are bound to dominate the marketplace. But if they are lackadaisical in so doing, they will lose out in the end.

What happens when a customer makes changes in his layout and returns to the original vendor for an upgrade or expansion? Without fail the Vendor's HO has no record of such changes. It has been Aptec's experience that feedback by way of information meant to correct official records are routinely ignored by the head-office. This is because no one at HO is tasked with the responsibility for doing so.

Concept drawings are prepared in each of the leading vendor's offices by a group of draftsmen and estimators called the **Sales Support Team.** It is this team that **receives** and **routinely ignores** feedback relating to configurational changes in the field and then insists on using outdated "as built" layouts from their obsolete records. We believe that vendors need to squarely include record-keeping as part of the responsibility of their Sales Support Teams. Meanwhile they can make a start by sending a draftsman to an existing plant to correct, vet or update their "as built" record when a repeat order is in the offing.

5 Examples Of Advanced Process Building Layouts

5.1 All Sandwich Panel Buildings

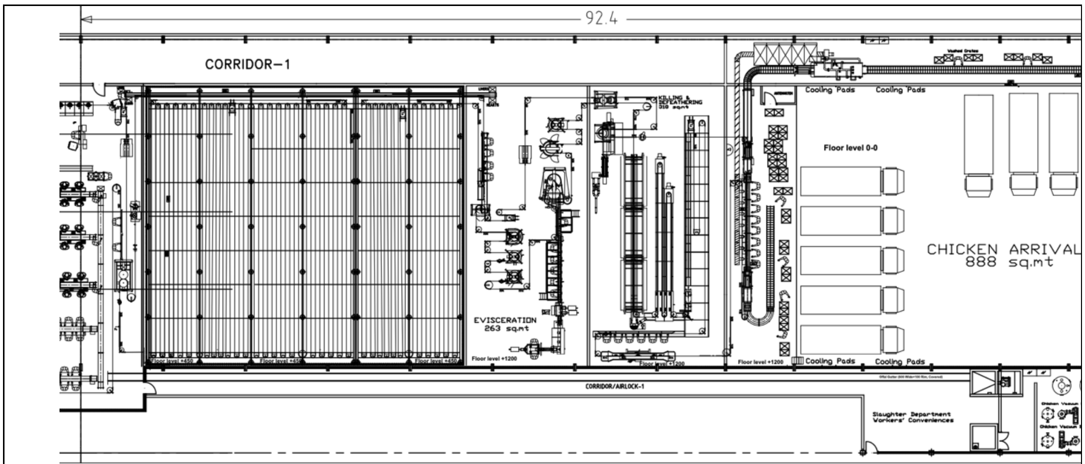


Figure 28 Showing plan of an all panel building meant to house an 8000 BPH poultry slaughterhouse to be constructed in Western India. The offal pit and associated machines are in part of the main shed, of which other details are omitted here for clarity. Note that this plant has provision for air chilling.

This style depends entirely on the use of polyurethane sandwich panels for walls around a steel frame and topped with a truss mounted steel sheet roof. Figure 28 shows the plan and figure 29 the elevation. This plant remained at the planning stage: it was never constructed.

5.2 Hybrid Buildings

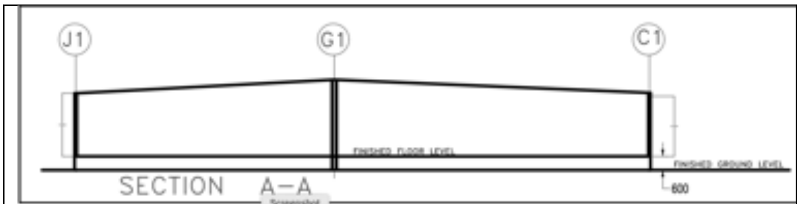


Figure 29 Elevation of the building shown in figure 28. The span width is 36.5m, with an off-central row of steel columns.

We present three variations of hybrid buildings here. The first example is a variant of a standard hybrid building designed by Aptec for Sri Lanka – catering to a climate with heavy precipitation. The second is a standard hybrid building with a starting capacity of 2500 BPH and a final capacity of 6000 BPH. The third and final hybrid layout is in figure 38, aimed at catering to a combined raw chicken and RTE products facility.

5.2.1 Hybrid Building With Sheet Roof

Based on discussions between Aptec and a local architect on the initial layout proposed for the Sri Lankan plant of 4000/8000 BPH capacity, it was suggested by the architect to enclose even the Inflexible Block within an overall sheet steel roof to protect against the heavy rainfall in that country. This left a considerable void between the sheet roof and the RCC slab cast over the Inflexible Block and we immediately set about arranging several service areas within that space.

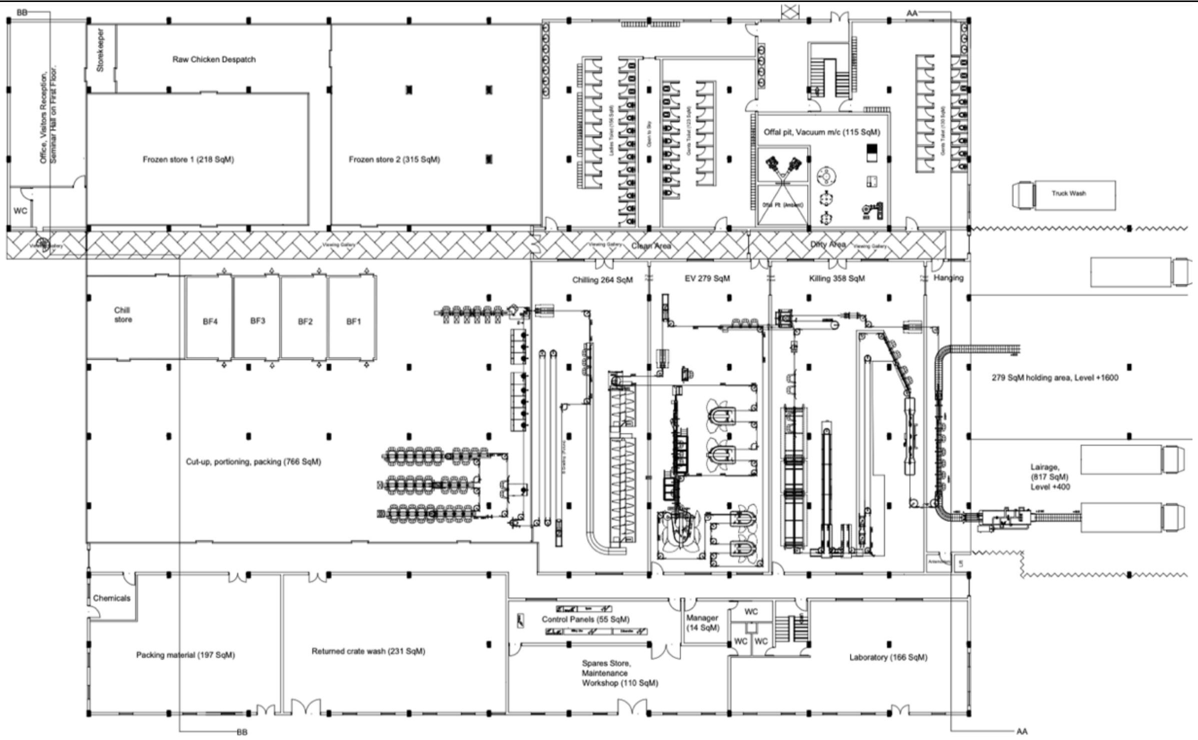


Figure 30 A 4000/8000 BPH slaughterhouse layout design for Sri Lanka. This design incorporates both Inflexible and Extrudable Blocks but the former is additionally covered by an extension of the sheet steel roof owing to the heavy rainfall in Sri Lanka. Because of this a lot of unused space became available for use in our design. Figure 31 shows how we used this space for service areas. And figure 32 shows how the viewing gallery extends through the Extrudable Block and leads all the way to the office block where visitors are expected to begin and end their tour.

An extension of the workers' rest rooms, an infirmary and a canteen complete with pantry, scullery and access staircases from both sides of the building to them were incorporated in the design and some of these appear in the elevation of the Inflexible Block in figure 31. Prepared meals are brought in by caterers and raised to the level of the pantry with the help of a product lift. The lift is located next to the ante-mortem test room on the live bird hanging section and has access from outside the lairage area.

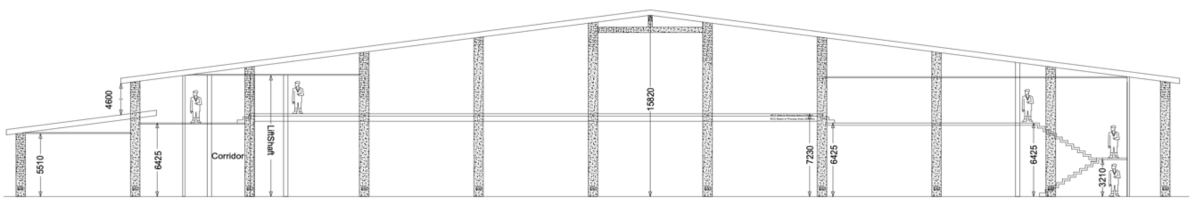


Figure 31 Elevation of a section through the Inflexible Block of the Sri Lankan slaughterhouse showing various service areas making use of the space between the RCC roof and the sheet steel roof.

The other elevation drawing is through the Extrudable Block of this building. It includes the office area and the portioning & packing hall and shows the viewing gallery. In this layout the Extrudable Block is expected to expand towards the left (in the plan view). The existing left wall of the building will move one block distance and align with the left wall of the office area. We believe this will create enough additional space for the target capacity of 8000 BPH. When this expansion occurs the existing chill store will either be extended by one grid distance or an additional blast freezing chamber may be added, depending on market requirements.

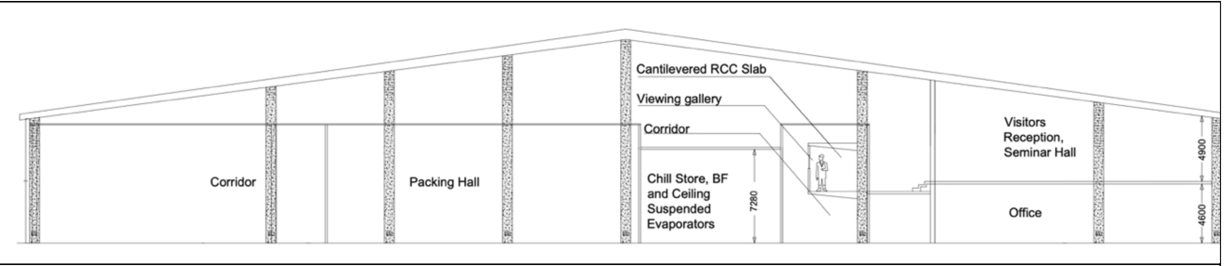


Figure 32 Cross section at BB-BB through the building plan shown in figure 30.

5.2.2 Standard Hybrid Building

Figure 33 shows the standard hybrid construction of a 2500/6000 BPH poultry slaughterhouse. The elevation is shown in figure 34 and the eventual 6000 BPH layout of machines appears in figure 35.

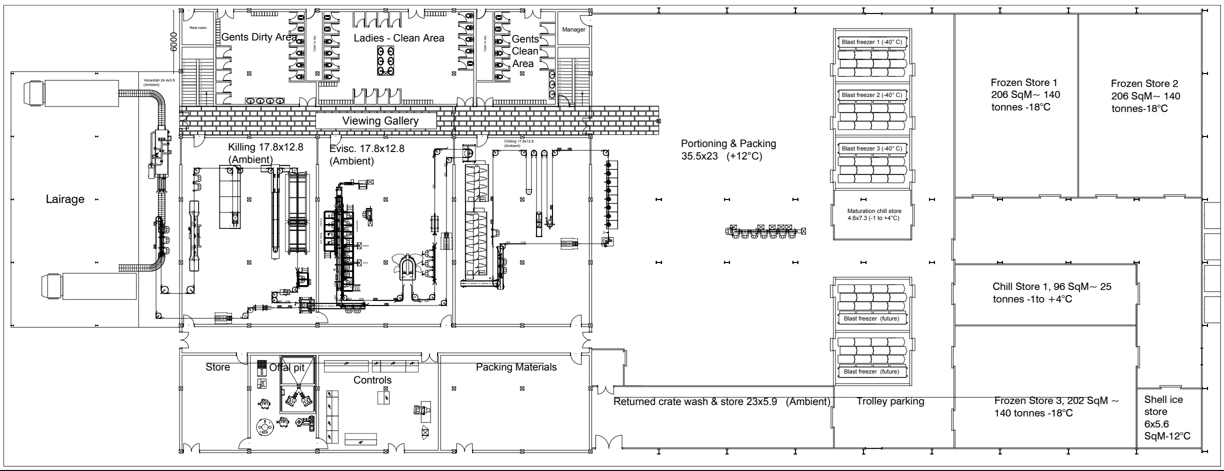


Figure 33 A 2500/6000 BPH processing building drawing showing the starting configuration. When you compare this layout drawing with the one shown in figure 35 you will notice that since the initial equipment placement was done right, expansion can occur with a very small downtime.

Over the workers' rest rooms lies the canteen and office area and you can see two staircases leading up to it. These same staircases also reach the viewing gallery, which in this case extends to a suitable vantage distance into the Extrudable Block. Note the 2500 wide aisle throughout the processing halls in the Inflexible Block – closed with panels but always available for taking in new machines when you expand. You can use this example to review all the design rules enunciated in this chapter.

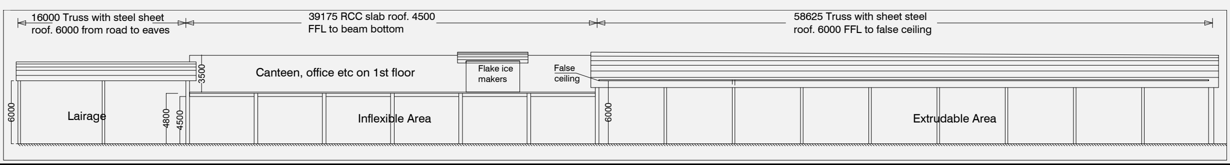


Figure 34 Elevation of the plan shown in figure 33. This layout is for a starting capacity of 2500 and a peak capacity of 6000 BPH. Note the dimensions and heights.

At 6000 BPH the layout takes on the form shown in figure 35. Note that none of the machines had to be moved – the building design and initial placement of machines had already anticipated expansion. Consistent with this policy, the vendor or consultant would also have released floor gutter and steel superstructure drawings to cater to the expanded configuration and those would have further reduced the downtime when expansion of the plant was undertaken.

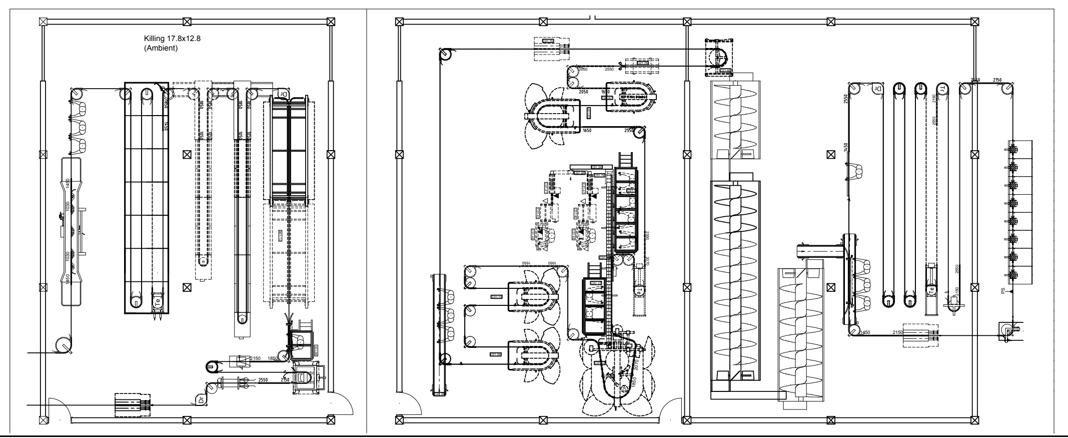


Figure 35 Except for the arrival and live bird hanging department all three halls within the Inflexible Block of the layout of figure 33 are shown here.

5.3 Common Building For Raw + RTE Poultry Products

Around 2013 a greenfield processing plant with an initial capacity of 6000 BPH, capable of doubling in the next phase, and designed for both raw poultry and ready to eat (RTE) poultry products was proposed by a customer in Pakistan. Aptec presented a layout to match the piece of land that the customer had acquired for the purpose. However, the customer chose to entrust the assignment to a firm of German butchers instead of assigning it to Aptec. Thereafter Aptec's contribution to the project remained limited to design of the slaughtering section, in keeping with the overall plot plan designed as shown in figure 36.

Some years later, the customer approached Aptec in search of a solution to a fundamental and persistent operational problems he faced – too much condensation on the sandwich panel ceiling throughout the plant. The problem was so severe that it impacted product quality adversely[21], and also caused great discomfort to plant personnel. It should be noted that the customer was reputed for quality throughout the region and the impact of this challenge to product quality was a serious concern.

Aptec submitted an answer which forms the subject matter of the chapter Design of Poultry Slaughterhouse - Engineered Ventilation for Biosecurity & Efficiency, which is a part of this Handbook. When you look at figure 39, you will find that it contains far fewer chambers than the RTE sections of figure 36 does. This was one of the main reasons for the problem faced by the customer. When air-space within a building is sub-divided into a myriad of hermetically sealed chambers, and all the chambers have different heights, it becomes difficult to engineer ventilation. Then stale and saturated air lingers everywhere. Excess moisture condenses on the ceiling, becomes a repository for aerosol contaminants and rains down on the product.

This design of figure 36 makes a useful case study and a means to review the rules enunciated in this chapter. Later, after an appraisal of this design, in figure 38 we present the rejected alternative design submitted by us. As he examines each aspect of the design, the reader will find it useful to refer to figure 38 to undersand Aptec's solutions to such problems, which were anticipated and catered for.

5.3.1 An Appraisal of The Raw + RTE Plant Layout

(a) Mixing Raw & RTE Meat Under The Same Roof

Raw meat always contains pathogenic bacteria which are eventually destroyed by cooking. To ensure that these pathogens do not spread to RTE products, it is essential to maintain strict physical separation between areas which handle them. When this is done, for instance, in accordance with the provisions of the University of South Carolina directives,[22] which states that cross-contamination of RTE products by raw products may occur if the layout does not provide for separation of these products, the designer can neither create nor recommend the design shown in figure 36.

These cross-contamination prevention guidelines were published in 1999 – long before the layout shown in figure 36 was prepared and submitted to the client.

Starting October 6, 2003, FSIS requires establishments with combined raw and RTE poultry to implement one of three risk-based alternative regimes for *Listeria monocytogenes* on certain RTE meat products, develop written programs to control *Listeria monocytogenes* and verify the effectiveness of those programs through testing[23]. There are hazards presented by ingress of several other bacterial species in such situations. We cover them adequately in the chapter on Microbes In The Slaughterhouse[24].

FSIS later published a checklist in 2018 on conditions prevailing in plants producing raw meat[25]. For live bird receipt, hanging, stunning and bleeding areas they specify design and construction and recommend maintenance of unidirectional movement of air from inside to outside (counter-current to product movement). We have developed this concept in detail in the chapter titled Design of Poultry Slaughterhouse – Engineered Ventilation for Biosecurity & Efficiency.

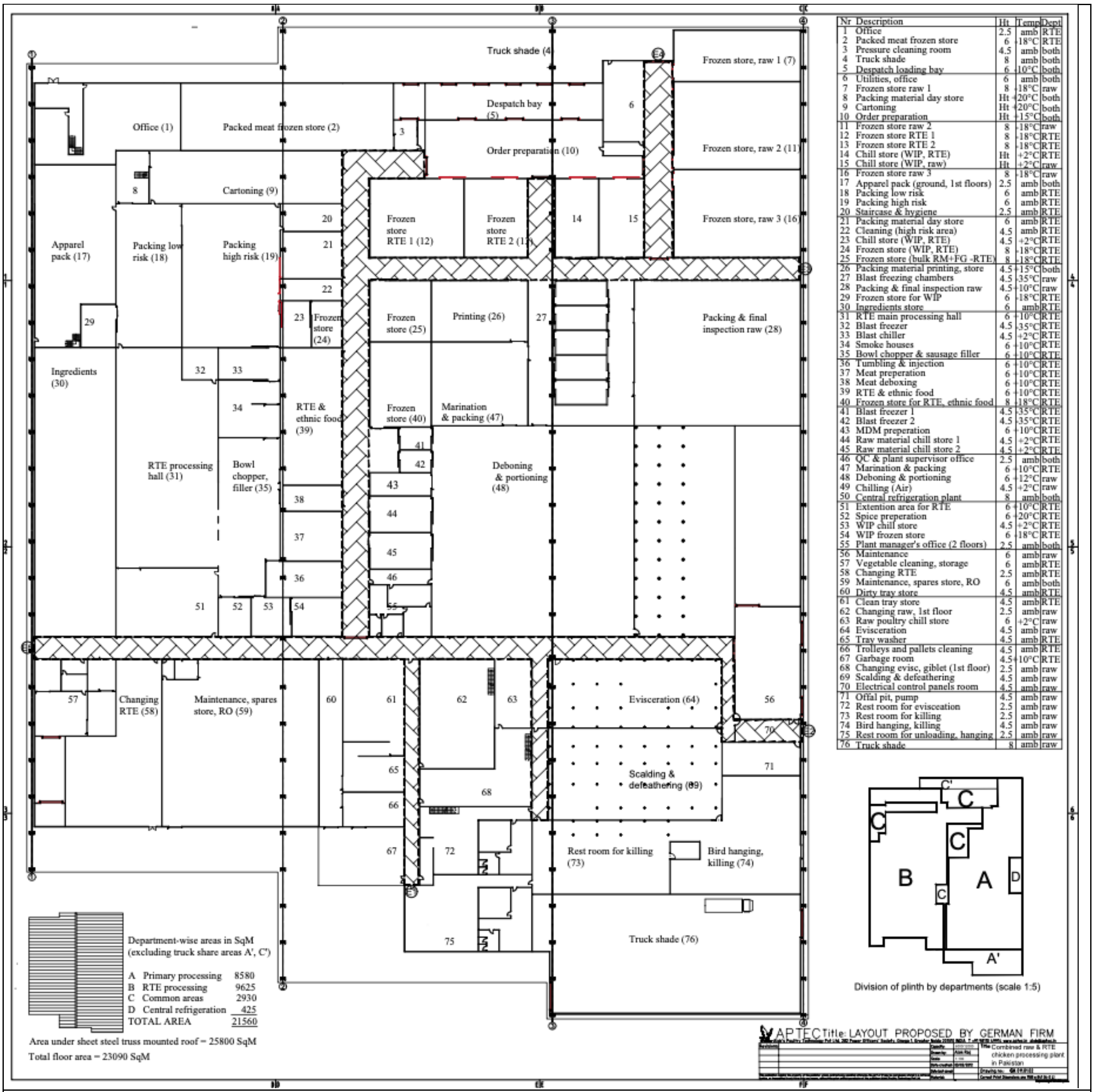


Figure 36 Showing the layout of a combined raw poultry meat and RTE products for 6000 BPH, expandable to 12000 BPH. The layout was made by a firm of German butchers for a client in Pakistan around 2013.

The RTE poultry products under the *Listeria* rule are those exposed to the environment after cooking, or to put it simply, products that come into direct contact with a contaminated surface after cooking. FSIS further clarifies that such exposure to a contaminated surface may occur as a result of shared space or equipment in steps such as slicing, peeling, re-bagging, cooling, semi-permeable encasement of product with a brine solution and other procedures.

Besides making the operations wide open to cross contamination, owing to the haphazard intermixing of raw and RTE processing areas, there are numerous other problems with this layout. Let us examine which of the rules and principles of design of poultry slaughterhouse have been flouted.

(b) Covered Area
Figure 36 has a plinth area of 2.30 hectares (5.9 acres) under a single roof. The Chinese plant of Jilin Baoyuanfeng[26] had a plinth area of only 1.6 hectares (4 acres) and when a fire occurred there, the damage was complete in terms of property and 121 in terms of human lives. **Remember, the bigger the area under one roof, the longer are your escape routes.**

There are five exit points or escape portals in this layout. These have been marked E1 through E5 in figure 36. Note that there are two exits only on one side of the building – each of the remaining sides being provided with only one exit. For a building of this dimension, this is inadequate. For a reasonable set of rules relating to emergency exits from sandwich panel buildings, refer to the compilation presented in the Chapter entitled Design of Poultry Slaughterhouse - Materials & Safety. You can also compare this with the reconstructed layout of the Jilin Baoyuanfeng plant presented there and decide the implications yourselves.

(c) Construction Material
All partition and external walls proposed in figure 36 are made of sandwich panels of various thicknesses depending on the desired working temperatures within. In section 3.2.2 and in the chapter on Design of Poultry Slaughterhouse - Materials and Safety, this matter has been covered in detail and recommended against, in the interests of safety.

(d) The Square Design Obsession
Architects are very fond of extolling the virtues of the square building design so popular in cold climates because it is perceived to be efficient in conserving heat in cold climates, exactly as it is efficient in cooling in warm climates. Yet it makes ventilation and natural lighting that much more difficult and expensive. In fact so important is this design obsession that we choose to cover it separately in another section, where we use one of the earliest versions of the German firm's design as an example of a square design and discuss various aspects[27].

That the square design adversely affects ventilation and consequently biosecurity, is discussed in various sections of the chapter on Design of Poultry Slaughterhouse - Engineered Ventilation for Biosecurity & Efficiency.

(e) Unnecessary & Dangerous Inclusion
Inclusion of a central refrigeration plant in the same building and under the same roof as the main processing plant is a dangerous neglect of one of the layout design rules enunciated above and particularly advised against in table 17. The risk is further enhanced because this section has been placed within a sandwich panel building.

(f) Oversized Departments
A design like this makes it impossible to expand departments that need more space either upon capacity expansion or because of operational or technological needs. Because requirement of expansion space for specific departments cannot be foretold at the outset, invariably space set aside against such contingencies are almost never quite right. This particular customer chose to install an air chill system. Look at the space set aside for doubling of air chill space for whole carcasses. Given the available height under the sloping roof, doubling of air-chilling space could have been provided for on a floor above it. Such a strategy could have reduced the cost and made the building more compact.

We have come across another customer in South Asia who decided to adopt air chilling in complete contrast to the norm of water chilling in this region. He was hugely unsuccessful as a consequence and had to shut shop within a few years because the local customers saw the dry appearance of air chilled carcasses as a negative product attribute. As in this case, that customer had also opted for a final, inflexible layout and had no space to switch over to water chilling.

(g) Two Storey Structure

In this layout workers are required to use the first floor of the plant to reach designated work areas. Note that there are six staircases to facilitate this. This means that the false (drop) ceiling, which is presumably also made of sandwich panels, must be strong enough to take the traffic and moreover, all of it must be at the same level. But when you look at the tabulation in figure 36, you will find that there are so many different levels suiting each department that it is not an easy task to chalk out the workers' travel routes on the first floor.

(h) Maze of Pipelines

Given that the first floor must carry all the utility pipes (water, steam, compressed air, vacuum, refrigeration) and power, control and signal cabling, as well as clear travel routes for personnel rising up and going down any pair of the staircases, and do so by negotiating level differences owing to different levels that the false ceilings are set at, design of the first floor would be even more complicated than the ground floor.

(i) Sarcophagus Design

The corridors are too narrow and incorporate too many bends to allow entry or removal of large items of machinery. Also, while they have not been shown here, the original layout drawing showed all the machinery already in place, without any clear indication of the route through which they might have been dragged to their final positions. Clearly, this building envisaged erection of sandwich panel walls after the machines had been positioned – in typical sarcophagus style.

We have also summed up a comparison of the features of this design, with the USDA directives and derived simple rules for designing combined product layouts in table 37.

Table 37 **Does the General Arrangement Layout In Figure 36 Conform With USDA?**

	USDA Rule	Compliance?
1	Exposed cooked product areas should be physically separated from other areas of the establishment. Non-pedestrian passage openings may be present for the transfer of product or supplies.	This rule means that personnel may not freely move from inspection, packing & despatch of ready to cook meat areas or areas preceding them to RTE areas where exposed cooked products exist or are processed. Should transfer of ready to cook meat need to be made from the former to the latter, it should occur through hatches in walls separating them – the hatches themselves being sufficiently small to prevent personnel to pass through. Alternatively transfer may occur through corridors or passages that are not used for general pedestrian traffic. An examination of figure 36 shows that this rule has been flouted in scores of locations within the layout. On the other hand, in figure 38, the corridor adjacent to the row of frozen stores is designed for movement of raw or ready to cook meat and is not to be used for general pedestrian traffic – such traffic moves over a separate gantry.
2	A ventilation system should be used to direct air flow away from exposed cooked product areas.	This layout drawing is not expected to reveal details of ventilation system. And may, if developed, have been presented as a supplementary drawing which we do not have access to. However, we can certainly speculate if such a planned ventilation system would or would not have worked here. Note the complex intermeshing of raw and RTE processing areas in the inset of figure 36. We believe it would have been impossible to design a ventilation system which might direct air flow away from exposed cooked product while at the same time maintain a counter-current air flow within the raw poultry areas as recommended in the chapter titled Design of Poultry Slaughterhouse - Ventilation for Biosecurity & Efficiency
3	Environmental control equipment such as fans and evaporator condensation pans should not be located above the product.	The general arrangement shown in figure 36 does not rule out the possibility of compliance with these rules.
4	Cooked product should be covered in rigid containers to protect it from contamination while in storage.	
5	Separate coolers and/or freezers should be available to use for exposed cooked product.	The general arrangement drawing of figure 36 already specifies separate freezing & chilling chambers.

5.3.2 Raw & RTE Poultry Products – An Alternative Layout

Figure 38 explains how Aptec's layout for a combined raw cum RTE plant differs from the one shown in figure 36. We have compared some of the salient points here, but it would be instructive for the reader to return to section 5.3.1 and compare each point raised there.

Let us examine the principal features of the layout in figure 38. It shows two production areas – raw chicken and RTE. They are physically connected by two passages. The first of these is a corridor running along the frozen stores which allows one to move trolley-loads of raw and ready to cook chicken from the slaughter and portioning section to the RTE section and to retrieve the trolley and crates used in the process. The second passage is a gantry that runs between these buildings.

Between these two passages lies the central refrigeration plant, close to frozen stores, chill stores, screw chillers and blast freezers so as to reduce pipeline cost and maintain comfortable running pressures in the pipelines. Yet this central refrigeration plant is also separated from everything by means of a road wide enough to allow trucks in for servicing it and fire tenders to reach it in case of any emergency. Note, a fire tender can access the central refrigeration plant from any direction.

How does one deliver raw meat to the RTE section? At the raw meat end of the corridor is a crate cum trolley wash (it is a small square structure located there) that allows one to thoroughly wash any trolleys, bins, crates or utensils that must move from the raw meat area to the RTE area. The long corridor itself is designed to be fitted with hermetically closing automatic, synchronized doors at its ends to eliminate any possibility of exchange of aerosols between the sections. Door one opens and you move into the corridor with your trolley-load of raw meat. As you do so, door two remains shut till you reach it. Then door two opens and lets you in even as door one shuts automatically and remains shut till you reach it on the return journey.

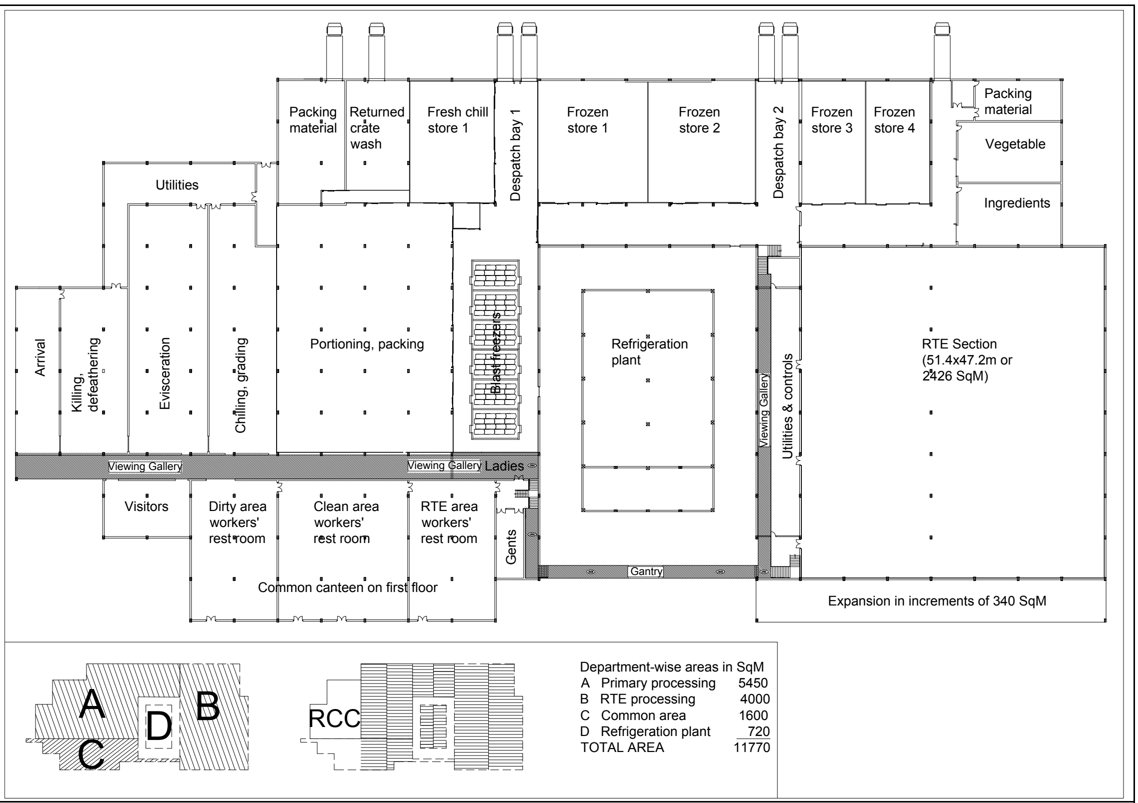


Figure 38 Aptec's alternative layout drawing shown here with minor modifications, was initially presented to the Pakistani client and got rejected. However the same layout drawing was presented two years later for an Indian project. From this layout you can easily understand how all the errors in figure 36 could easily have been corrected.

In this way trolley loads of raw meat are manually delivered to door two and left there. Then, when the raw meat person returns to his part of the building and his door shuts, the trolley load may be retrieved by an RTE person, taken to the staging area (shown as the space adjacent to and under the staircase) and transferred to RTE area utensils. This SOP ensures "non-pedestrian movement of materials", a phrase that occurs in the standards.

Raw and frozen RTE products have separate frozen stores and despatch bays. But because they are located close to each other and on the same side of the building, it is possible to use a common reefer to send shipments to retail outlets in the same reefers without having to duplicate transportation.

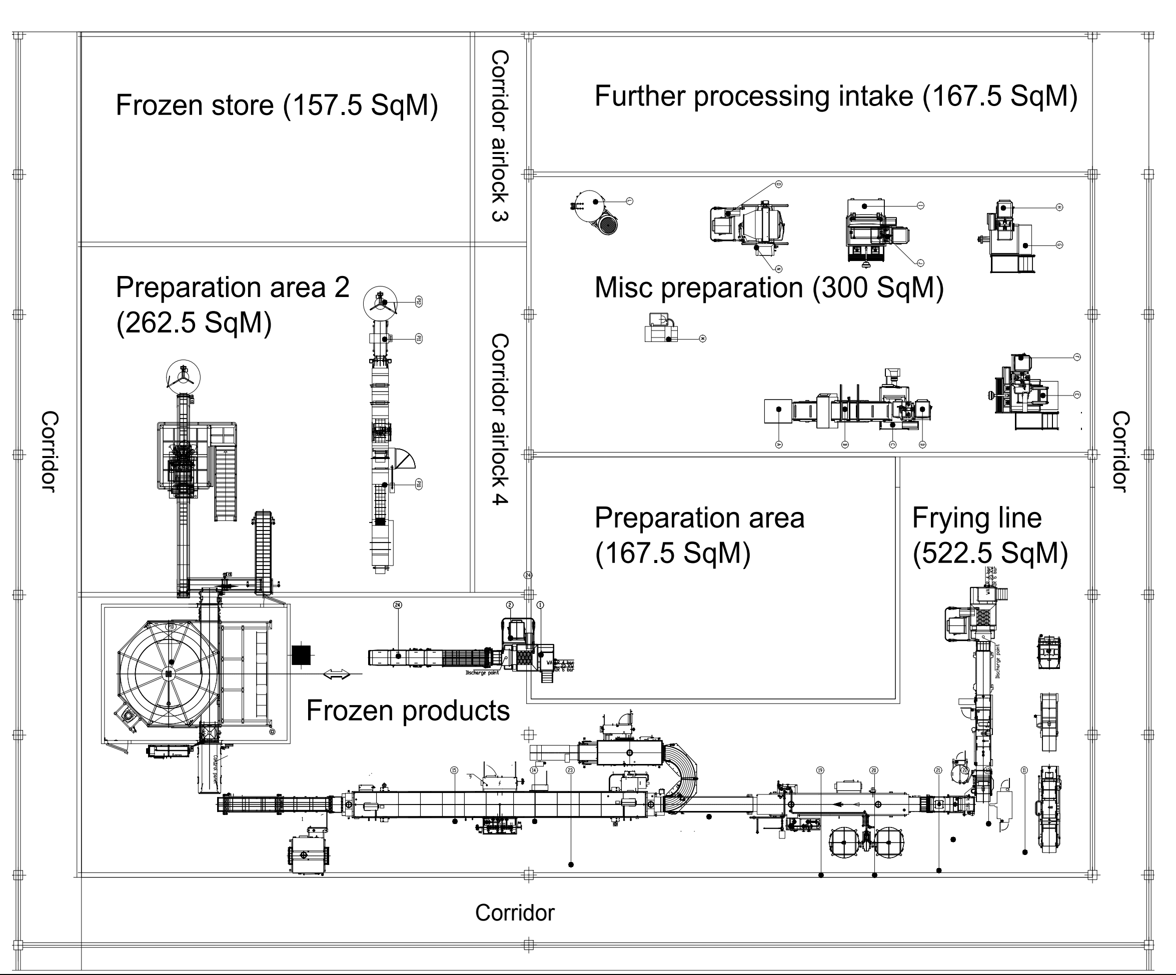


Figure 39 Layout drawing of a suitable RTE plant drawn by an Iranian-British expert on RTE projects. It measures 50x40m and can easily fit into the layout drawing of figure 39 into the reserved space of 2426 SqM for the RTE department

There are separate wash rooms for raw and RTE workers and since the first floor of the service block is available for expansion, it is possible to expand these sections and cater to an increase in number of workers. RTE workers use the gantry between buildings for commuting and this gantry is shared by visitors. Note that the gantry is high enough to give access to trucks to the central refrigeration plant.

In the layout shown in figure 36 an extraordinarily large area of 9600 SqM was allocated for RTE. This was probably because, having already decided on a square sandwich panel building, the planners were obliged to justify it by allocating unnecessarily large spaces for some departments. However, even if we continued to cater to such their extraordinary high area allocation for RTE in layout 38, the total built-up area would still remain only around 17000 SqM, thereby reducing the total constructed area by approximately 20% !

Several years later, in the course of planning another combined raw + RTE poultry processing plant, we offered this basic design, to which an experienced Iranian-British expert on the design of RTE facilities offered the layout measuring 50x40 metres for the RTE section. This layout appears in figure 40. As you can see, the required area of 2000 SqM (excluding all service, utility and frozen finished product store areas which are already provided for in other parts of the building), could quite easily fit into the RTE provision of 2426 SqM of the layout drawing in figure 39. This implies that the designed allocation of space for RTE in figure 36 was far in excess of requirements.

6 The Square Building Mindset

Functional area	Square design	Hybrid design
Live bird arrival	1840 SqM	2130 SqM
Killing, EV	1220 SqM	1230 SqM
Cut-up	2840 SqM	2850 SqM
Workers rest	1990 SqM	1950 SqM
Maintenance	1050 SqM	1140 SqM
Utilities	900 SqM	1050 SqM
Further process	3730 SqM	3680 SqM
Freezing, Wareh.	4440 SqM	4630 SqM
Vegetables	840 SqM	840 SqM
Packing matl.	980 SqM	980 SqM

Functional area	Square design	Hybrid design
Despatch	1000 SqM	1000 SqM
Corridors	820 SqM	1300 SqM
Total area	23000 SqM	24050 SqM
Area ratio	1.000	1.054
Bldg perimeter	642 M	732 M
Ext surface area	53224 SqM	54322 SqM
Est avg height	8500mm	8500mm
Surface:volume	1.000	1.056
Corridor ratio	1.000	1.58

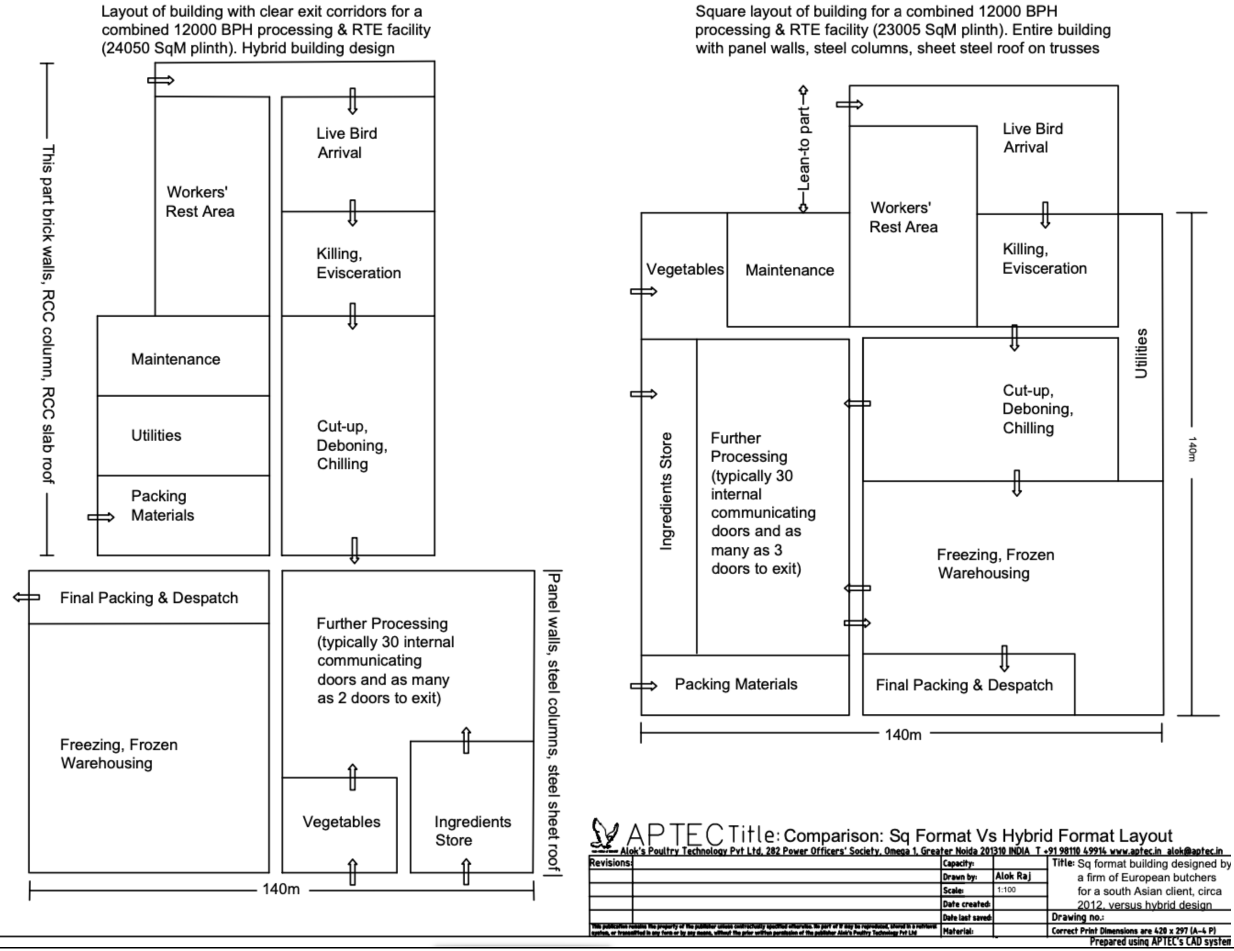


Figure 40 A comparison of physical properties of alternative building shapes proposed for a raw chicken cum RTE facility. For comparison we have retained the design floor area of 23000-24000 SqM of the original square design in our submission although we have shown above that this is an excessively large area

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

For such constructions, structural engineers instinctively favour square plinths because it saves them a lot of design time, besides allowing them to tom-tom the virtues of exterior surface area to volume ratio – i.e. high thermal efficiency – whether internal areas are to be cooled or heated, that is achieved by this design method.

What are the facts? In a square design the engineer encounters less freedom to change the building's side dimension than in a rectangular design - you cannot change the dimension of one side without simultaneously changing the dimension of all four sides. A square plinth also increases the distance between utilities such as a central refrigeration plant and target refrigeration zones within the building. So some of the savings in the building's so called thermal efficiency does get neutralized – for example in increased pump load in the refrigeration circuit, assuming, in the first place, that the designer has followed the codes and placed the refrigeration compressors well outside the confines of the building. The designer of the layout shown in figure 11 has clearly not done so, simply to reduce pipeline lengths. Likewise the designer of figure 36 has not done so either.

Additionally, for buildings that make extensive use of ammonia as refrigerant and install large amounts of sandwich panels in the interior, making *buildings within buildings* as it were, as commonly done in the food processing industry, not only do distances to exits increase, but a greater potential exits for pockets to trap leaked ammonia between the false (drop) ceiling and the roof sheet and elsewhere.

Further, once the structural imperative of square building is a given, the process flow is required to fold back and forth in a zigzag fashion until it is forced to fit into available spaces. Remember - the layout principle in slaughterhouse design follows certain cardinal rules – department location must follow **a gradient of cleanliness**. Any attempt at repeated folding of process flow ignores this rule. To make amends designers then resort to complicated air flow routes, completely compartmentalizing certain sections in the effort and creating more pockets for stale air, aerosol contaminants and leaked ammonia to get into and stay trapped. Refer to section 5.3 where we mention how the Pakistani customer complained of saturated air trapped in the maze which was created by the designers of that building.

Does a square building actually make a compact design, reducing the need for outlying external work spaces? We think not - take a look at the reconstructed layout of the Jilin Baoyuanfeng plant in the chapter Design of Poultry Slaughterhouse - Materials & Safety.

Here the workers' entry gates on the south side of the Chinese plant requires workers to also exit from these gates – with all other gates having different functions. Imagine the complex exit routes when you consider that the straight distance into this 120m x 140m building could be as much as 100-150 metres, and that the actual escape distances could be twice or thrice that number because of zigzag placement of work flow. All these things result in a more hazard-prone design. Then, returning to the design under discussion, how much worse the situation would be for an even bigger building!

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

To test this hypothesis in the context of this study, we made a comparison of the two different building styles suited for complete processing of 12,000 birds per hour and some RTE products derived from the same. This comparison is presented in Figure 40. The square design is based on an early iteration of the design that resulted in the figure 36 variant. Now compare it with Aptec/s design presented on the left in figure 40.

If we assume that both versions have an average height of 8.5 metres, then the external surface area of the Aptec's version is actually only 5.6% higher, even as its plinth area (usable space) is also higher by 5.5% in comparison with the square version! So there is a near parity of surface areas for unit work area.

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

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

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

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

Table 41	**A Glossary of Terms Used in This Chapter**
Aggregate	A hard material used in concrete to add texture and unique graining; a fine aggregate is less than 1/4" in diameter, like sand, and a coarse aggregate is up to 1.5" in diameter, like crushed gravel or granite.
Antimicrobial Flooring	Typically contains 2,4,4' - Trichloro-2'-Hydroxy Diphenyl Ether or any other variant of ***trichlosan*** which is the germicide also found in some brands of toothpaste. This material works by inhibiting ATP-amino acid reactions, thus blocking metabolism in microbes, as a result of which they perish. In this case the antimicrobial molecule is mixed in the floor material and gets progressively released through attrition of the floor by traffic on it. Other additives may also be used.
AptecApp	This is an App created by Aptec and uploaded on its website. The App allows you to choose from among five different slaughterhouse sizes, permitting you to configure dozens of operating parameters and the financial feasibility of your project gets instantly recalculated. Bundled with the App is a drawing for all five plants. This App is free for anyone to download and use.
ASHRAE	Acronym for **A**merican **S**ociety of **H**eating, **R**efrigeration and **A**ir-conditioning **E**ngineers.
Aspect ratio	In this case, the ratio got by dividing length by breadth of the plot of land.
Below-grade	Partially or completely below ground level.
Bursa	Also called the preen gland, located just above the cloaca of a bird. It exudes a bitter oily liquid which birds spread over their feathers to make them waterproof. Because of its disagreeable taste, this gland is cut off and removed during processing.
Carcass	The dead body of the chicken. When used in this Chapter, the term denotes both the intact dead body with feathers on and the eviscerated and dressed intact (un-portioned) dead body.
Caulk	Type of adhesive; used often between floor and appliances, like around toilet or bathtub; can be acrylic, butyl, latex, silicone or urethane.
Coop	A cage in which live chicken are transported from the farm to the slaughterhouse. These are foldable, top opening cages, two standard sizes of which are in use in India.
Crop	Crop is the first of three stomachs of a bird where it temporarily stores food and where digestion begins. It shows as a swelling in the neck when a bird rapidly swallows a large quantity of food. The other two stomachs are proventriculus and gizzard. Gizzard is like a grinder where stones or pebbles a bird deliberately swallows help grind food such as grains and seeds to extract nutrients. For this purpose a gizzard has a horny yellow lining and is a strong muscular organ and one of the edible offal.
Curing	The point of complete drying of floor or casting.
Dado	A wide extension of the floor which is made to ride some distance up the wall so as to present a hard wearing and continuous surface. Also see skirt.
Deboning	The process of removal of bones from a chicken carcass to produce boneless portions.
Dock leveller	Because of varying height levels of the deck of trucks and reefers, a dock leveller is fitted in a loading bay to create a ramp and this allow smooth loading. A dock leveller needs a foundation which is built below grade level in the dispatch dock.
Dock shelter	Like the boarding platform leading into a commercial aircraft, a cover is required to connect to and seal off the entrance of trucks and reefers with the despatch bay opening to prevent entry of flies.
Dirt retention	Dirt retention of the floor finish is its ability to embed soil, dirt and grime. Slaughterhouse design and choice of flooring material is always a compromise between dirt retention and traction. It is impossible to smoothen any floor to a sufficiently high level of dirt retention that prevents adhesion of bacteria. This is because many of the pathogenic and otherwise undesirable bacteria have the ability to generate biofilms which are adhesive colonies, even on surfaces as smooth as glass.
Drafting	The process of making engineering drawings.
Draftsman	A person who (in this case) makes engineering drawings for poultry slaughterhouses, either simply for estimating cost of a commercial offer or for construction at site.
Evisceration	The process of removal of viscera (integral organs) of the chicken as part of the process of slaughtering.
Evolution	The gradual improvement in design of machinery for better and more efficient performance. Here we have estimated the progress of evolution of specific machines to signal that your layout may soon need adjustment if the evolved design of machine you purchase, requires it.
Extrudable area	A term coined by Aptec to refer to the processing departments that follow spin chilling and are built with a truss mounted sheet steel roofing. The portioning and packing area within it is bound by utility and service rooms and buildings on two sides. However, one side, representing the end of the building, is not hemmed in and can be extended. In fact, such an extension will require the utilities and services to follow suit. Therefore we call it an extrusion. Note how a design is made fit for extrusion by studying figure 14.
Feed withdrawal	It is necessary to stop feeding chicken some hours before they are slaughtered. This is called feed withdrawal. It is done to improve the evisceration process and to obtain a higher quality of chicken meat.
Frost heave:	Frost heave is a form of frost action, a physical weathering process involving the cyclic freezing and thawing of water in soil or rock. Heave in this context refers to the upward movement of the ground surface that occurs in response to the seasonal formation of ice in the underlying soil. When a man-made construction is built over an area that is subject to this phenomenon, the structure gets damaged. Frost heave occurs under all industrial floors containing sub-zero temperatures above them, and results in floor cracks over time. Once such cracks appear, water from the operations within the plant may leak into the foundation area and further accelerate the phenomenon. This happens over time, regardless of whether the sub-floor structure contains thermal insulation or not.

FSIS	The **F**ood **S**afety and Inspection Service, an agency of the United States Department of Agriculture (USDA), is a public health regulatory agency. Standards and rules framed by the FSIS are routinely followed by industry in most countries.
Gantry	A tall and large bridge-like structure connecting (in this case) two buildings for placing pipelines etc on. The gantry defined in this chapter is set sufficiently high over an internal road so as to allow passage of trucks and fire tenders.
Gizzard	See crop.
Glazing	A clear substance that is applied to the surface of a door or window to allow one to see beyond it and permit light to pass. Specifications for glazing in the poultry slaughterhouse have been listed in table 18.
Grade Level:	Pertains to the construction level comparative to the ground surrounding it. On-grade is when it is at ground level, while below-grade is below ground level and above-grade is above ground level.
Granolithic	Dewatered granolithic concrete flooring is laid using rich concrete made with specially selected aggregate of high hardness, surface texture, and particle shape, which is adapted for heavy engineering factories providing high traction. Dewatering makes it compact and removes voids. Dewatering is done by laying a plastic sheet after casting and connecting a vacuum pump to a hole in the sheet. Atmospheric pressure bearing down on the sheet causes the concrete to lose excess water and air from voids.
Grid	Imaginary lines forming a matrix based on which a layout is drawn. It is important to have uniform grid spacing when preparing a layout drawing.
Grinding and polishing	This refers to the smoothness and true slope of floor in the processing areas. All floors must slope towards the nearest floor-gutter by not more than 0.5%. Floors must be smooth, have a consistent slope and yet exhibit good wet traction. It helps to use natural stones as opposed to vitreous tiles because you can grind away some of the slope errors in the case of the former. Always make sure not to attempt a highly smooth mirror finish when you do so or you will destroy traction.
Ground humidity:	The amount of water vapor in the floor and/or flooring substrate. When high moisture levels exist in the substrate, application of any polymer flooring will result in failure as the trapped moisture will puncture the impermeable polymer surface in a bid to exit. The true reason why polymer flooring often fails in India is that the application was done without extracting floor and sub-grade humidity.
Halal	The Islamic ritual method of slaughter. Its definition varies according to the local community of clerics and there is complete lack of uniformity over the Islamic world over its definition. For this reason the Fiqh Academy, which is a widely recognised authority on the subject in India has been referenced in this Chapter.
Ice lens	A lens shaped compact mass of ice that may form under a building foundation through the action of frosty conditions. An ice lens exerts an upward pressure and eventually damages the foundation and floor of the building.
Inflexible Block	A term coined by Aptec to refer to processing departments like arrival and live bird hanging, killing and defeathering, evisceration and spin chilling, which together form a block that one cannot expand because it is surrounded on all sides by utility and service rooms. Therefore when you are designing for growth, it is best to plan and construct this block to suit the final capacity of your plant and leave a corridor or aisle of sufficient dimensions to allow you to wheel in and properly orient large machines as they are needed from time to time.
Lagoon	Wastewater from a poultry slaughterhouse is mostly generated in the primary processing shift, when birds are slaughtered. After slaughter, the plant is washed with germicides and disinfectants. This wash cannot be allowed to pass through a liquid effluent treatment plant which uses a biological treatment step (immobilized enzyme system) as a means of pollution control. Because if it passes undiluted, it would kill the useful bacteria that are kept alive and immobilized in this processing step. It is therefore necessary to pool the entire 24 hours' discharge from a poultry slaughterhouse, (during most of this period the slaughterhouse discharge being benign). This helps dilute the lagoon's contents. Then this diluted liquid passes through the biological treatment step and it works properly. There is therefore almost a day's lag between generation of liquid effluent and its treatment. When wastewater is held in this manner, anaerobic digestion takes place, which generates a smell nuisance. To prevent this, aerators are often deployed.
Lairage	Parking place for truckloads of chicken at the slaughterhouse.
Layout	A drawing showing the dimensions and relative positions of elements of a slaughterhouse, based on which it is required to be constructed and populated with machines.
LEAP design	Is an acronym for **L**ow investment **E**xpandable (semi) **A**utomatic Processing **P**lant, first designed by Aptec in Nov 2011. It is now being promoted in the developing markets worldwide by Meyn.
Line frequency	The line frequency in India is 50 cycles per second or 50 Hertz. First and second generation electric stunners administer electric shock to birds at this frequency. It has been shown that a much higher frequency, generated within the stunner, is more efficient than line frequency stunning.
Methyl isocyanate	See sandwich panel.
Offal	Organs and structures that are removed in the course of slaughter. There are two kinds of offal in poultry slaughter – edible offal such as heart, liver and gizzard and inedible offal like intestines.
Offsite	A supporting facility that is not a direct participant of the main process as a utility is, but is nevertheless a secondary participant in the overall facility. In our context, a captive maintenance facility for the unit's fleet of trucks would constitute an offsite.
Permafrost	Permafrost is any ground that remains completely frozen (0°C) or colder—for at least two years straight. These permanently frozen grounds are most common in regions with high mountains and in earth's higher latitudes - near the North and South Poles. Permafrost covers large regions of the Earth.

Plucking	Removal of feathers.
Pneumatic tools	Tools that use compressed air for their operation.
Polymer flooring	A large number of synthetic floor topping materials are available for industrial plants. Among them are polyurethane, methyl methacrylate (MMA), epoxy, urethane and other synthetic resins with or without grit and stone chips added. Typically unless all sub-floor moisture is carefully removed and subsequent ingress of moisture is blocked, all these flooring types fail in the typical, wet environment of a slaughterhouse.
PUR/PIR	See sandwich panel.
Polystyrene	Popularly known as thermocole. Figure 26 shows a blown polystyrene block supporting one tyre of a car. Such blocks are regularly used as sub-floor insulation. A section of foundation of a frozen store floor is shown in figure 25 where this material has been used for insulation.
Rebars	Steel bars specially shaped for reinforcement of concrete structures.
RTE	**R**eady **T**o **E**at products, such as sausages, salami, burger patties and so on, formed by cooking or smoking raw poultry meat in this context.
Sandwich panel	A thermal insulating structural sheeting made by sandwiching a specific thickness of polyurethane (PUR) or poly-iso-cyanurate (PIR) between two thin sheets of galvanized or powder coated steel or one or both layers of stainless steel. No matter how much the vendor insists otherwise, the insulating material is combustible and when combustion occurs in limited air, a deadly lethal gas called methyl isocyanate is generated. Extreme caution must be exercised in designing buildings with this material. Always provide emergency exits to enclosures made with sandwich panels.
Sarcophagi	Singular sarcophagus. A stone receptacle for preserving mummified corpses, typically in ancient Egypt. In this chapter this term is used to denote layout designs where machines are tightly packed together and placed within chambers which allow little access for maintenance, repair or replacement of worn out machines.
Scaffolding	A temporary platform made of steel plates or wooden planks for working on during construction of a building. In our context it stands for such a platform on top of which reinforced concrete is poured and allowed to set and cure. After that the scaffolding is removed and the concrete slab is left in place as part of the building.
Scalding	After killing and bleeding, chicken are dipped for a short period in hot water to loosen the feathers. This process is called scalding. The degree of loosening is a function of dwell-time and temperature and an upper limit exists for each, beyond which chicken get partly cooked. This is why maintenance of a steady and accurate temperature setting, unaffected by several environmental and other uncontrollable factors, is crucial for a good scalder design.
Screed	As a verb, it is the process of levelling a floor or layer of concrete with a straight-edge using a back and forth motion while moving across the surface. As a noun it refers to a levelled layer of material (e.g. cement) applied to a floor or other surface.
Services	In the context of the poultry slaughterhouse a service facility is a canteen or a workers' rest room or laundry for plant workers' apparel.
Shackle	Shackles are used to restrain a prisoner or captive. In our case shackles are a series of appropriately designed stainless steel loops held together at specific intervals along a chain, which, in turn, forms a part of an overhead conveyor. Shackles are the features from which chicken are hung and transported by the overhead conveyor as they progress from machine to machine while slaughter is performed.
Skirt	A narrow extension of the floor which is made to ride up the wall some distance so as to present a hard wearing and continuous surface. See also dado.
Slot drains	A special type of custom-designed stainless steel drain which is embedded in floors just below grade, to carry away water from processing areas. Aptec recommends its use only in the Extrudable Block.
Steel deck construction	An RCC floor/roof slab design in which a steel sheet forming part of the load bearing composite is used in high-rise city buildings. The steel sheet also functions as a permanently placed scaffolding. This kind of roof slab is not appropriate for poultry slaughterhouses.
Stone flooring	Naturally occurring stone used for flooring, like granite, marble, limestone, slate, sandstone, Kota, Mandhana and Kaddapah. Of these only Kota and Mandhana are suitable for food processing plant flooring in India and Margalla in Pakistan. Local stones found in other parts of the world may also be suitable provided they polish to a non-porous, high wet-traction finish, are hard wearing, are inexpensive, strong and resistant to fatty acids and prolonged exposure to wet conditions. Never polish stone flooring to a high mirror-finish as it reduces traction to the point where, with the help of fat on the floor, people skid or slip and fall.
Stunning	Chicken are usually given an electric shock before they are killed. Several types of stunning methods are in use worldwide, all claiming to promote humanitarian treatment of chicken because of the plausible belief that stunning reduces trauma. Variations of stunning method include gas stunning where birds are progressively killed by exposing them to increasing concentrations of carbon dioxide. This is called gas stunning or CAS (**C**ontrolled **A**tmosphere) **S**tunning. Electric stunning at frequencies well above line frequency is used in India.
Sub-floor	The structural foundation for a floor that provides support. It is typically covered with a floor covering to create an even surface with traction and an aesthetically pleasing appearance.
Technical lighting	Standards call for specific intensity and colour rendition of illumination at the worktable or work-level in a poultry slaughterhouse. This is generally specified by the consultant and differs from architectural and emergency lighting which is the domain of the plant architect.

Terrazzo	A hard, durable type of flooring that is produced by mixing stone or marble chips in the cement and sand matrix. When the matrix sets, the surface is polished for a smooth effect for residential buildings and a less smooth finish for industrial floors which require traction.
Trichlosan	See antimicrobial flooring.
USDA	The **U**nited **S**tates **D**epartment of **A**griculture, whose published standards and recommendations are followed by the poultry industry worldwide.
Utility	Plant utilities refer to the various systems and equipment that play a supportive role to the main activity. For instance the electrical system, refrigeration system, compressed air facility and others constitute utility for a poultry slaughterhouse.

Endnotes

[1] Microsoft Visio as a flowcharting tool.

[2] In 2021, around 133 million tonnes of poultry meat were consumed worldwide, making it the most consumed type of meat. Projected poultry meat consumption worldwide from 2021 to 2031. https://www.statista.com/statistics/739951/poultry-meat-consumption-worldwide/

[3] This chapter is to be uploaded by the end of 2023.

[4] *Ibid.* To be uploaded by the end of 2023

[5] Consider a restaurant selling biryani. One chicken portion such as a drumstick or wing must be present in each serving. When the carcass is overweight, the chicken portion weighs more than the restaurant had planned and since he cannot charge his customer extra for the increased weight of chicken he serves, he cannot pay the slaughterhouse extra for having fattened his bird beyond his requirements. So who loses? If you are an integrator-processor, you lose. If you are a merchant processor, and charge processing fees per kilogram or per bird, the farmer loses.

[6] Eight inch shackle pitch is also in use, mainly for processing breeder culls. Also for some unknown reason all locally manufactured plants use this pitch for broiler plants.

[7] Unless you use full automation here with 6000 products or 8000 products per hour capacities. Aptec does not recommend these machines because Indian farming method cannot prevent birds from swallowing stone grit and this wears down machine parts, leading to very frequent replacement of machine parts. This in turn erodes your profits.

[8] Guide to Designing a Small Red Meat Plant with Two Sizes of Model Designs. Arion Thiboumery, Editor, North Central Regional Center for Rural Development. http://www.extension.iastate.edu/store or Iowa State University Extension Distribution Center 119 Printing and Publications Bldg., Ames, IA 50011 Phone: 515-294-5247, Fax: 515-294-2945 E-mail: pubdist@iastate.edu

[9] The slaughterhouse project requires a lot of land, not only to accommodate the various buildings and facilities, but mostly because poultry slaughter requires a lot of water, and the process produces as much wastewater as it takes in. This has to be treated before it can be discharged and In India the authorities have placed unreasonable restrictions on discharge of treated wastewater. So in effect it is virtually impossible to specify how much land will be required for wastewater treatment and utilisation for irrigation of your premises for a project of a given capacity. Under Indian low a project will pass muster if it owns sufficient land for using up all its treated wastewater for irrigation, or if the promoter has a written agreement with adjacent village(s) for disposal of treated wastewater for irrigation, and if the land passes zoning laws.

[10] *Ibid.* To be uploaded by the end of 2023

[11] *Ibid.* To be uploaded by the end of 2023

[12] Before Aptec introduced the LEAP concept in 2011, plant capacities sold by all major plant vendors were arbitrarily designated as 1000, 2000, 3000 BPH and so on, up to 12000 BPH. Aptec chose to fix the LEAP plant capacity not on such arbitrary figures, but in keeping with the limiting capacity of the machine among those that were put together. Here the plucker model JM32 was that limiting machine and in combination with a jacuzzi scalder, then available from Meyn, it could reliably process 1300 BPH. With the subsequent introduction of the Jet Stream scalder, JM32 can process 1500 BPH. The single section of these two differ by a mere 100mm in length.

People often ask whether the given LEAP layout can be served by Marel. No it cannot. Because Marel sells three-pass scalders and the orientation of every machine and every processing step that follows the scalder is totally different. We doubt whether the arrangement can be made as compact as LEAP with Meyn equipment.

[13] Refer to the Chapter titled "Evolution of Rendering Plant Design" available on the Aptec website. General plan and elevation for such a building is given there. The chapter traces the evolution of rendering design and points out how some perfectly reputable European vendors continue to peddle antiquated layout designs out of sheer mental lethargy.

[14] This topic is adequately covered in the Chapter titled "Evolution of Rendering Plant Design" available on the Aptec website.

[15] *Ibid.* To be uploaded by the end of 2023

[16] *Ibid.* To be uploaded by the end of 2023

[17] Historic understanding of frost heaving, https://academic-accelerator.com/encyclopedia/frost-heaving states - Urban Hjärne, a Swedish chemist, geologist, physician and writer first described the effects of frost on soil in 1694. Since the molar volume of water expands by about 9% when it phase-changes from water to ice at **its bulk freezing point**, the maximum possible expansion due to molar volume expansion is by the same percentage. If ice is still tightly constrained laterally, the expansion will cause a vertical lift. In 1930, Stephen Tabor, Dean of the Department

of Geology at the University of South Carolina, showed that the vertical displacement of soils in frost heave can be significantly greater than that 9% due to molar volume expansion because **liquid water moves towards the freeze line** within the soil.

[18] FAO document Freezing and Refrigerated Storage in Fisheries. FAO Fisheries Technical Paper – 340, 1994, Food And Agriculture Organisation Of The United Nations, W.A. Johnston, F.J. Nicholson, A. Roger and G.D. Stroud, CSL Food Science Laboratory Torry, Aberdeen, Scotland, UK

[19] Floor Frost Heave Protection Design Guide, Type FLX. Thermon, 100 Thermon Drive, PO Box 609, San Marcos, USA, TX 78667-0609 Phone: 512-396-5801, Facsimile: 512-754-2431, 800-730-HEAT www.thermon.com

[20] This may appear to the reader as too autobiographical for inclusion in a handbook, but we believe this tale sets the context for it. So we request your indulgence. Following an offer to take up representation for them in India by Meyn in April 1998, this author carried out a survey of all six poultry slaughterhouses that had been established till then. It turned out that other than VH at Pune, the remaining five were doing badly because they were planned and built wrong as they had no experience in the field and had received little hand-folding of value from their overseas vendors. So his author agreed to take up the offer provided he was at least partly compensated by Meyn for bundling free consultancy as an incentive. Meyn agreed and was soon able to offer customized layouts and lots of hand-holding completely free of cost to its customers. So Meyn soon emerged as the dominant player in India and several neighbourhood countries, Pakistan included. After this author retired in mid 2018, some vendors took to imitating this method, but they lack the experience and diligence to offer useful service. This Handbook project was taken up by Aptec to help protect the industry from such ill-equipped hand-holding.

[21] How dripping condensation from a sandwich panel building can adversely affect product quality has been covered in the chapter Design of Poultry Slaughterhouse - Ventilation for Biosecurity & Efficiency.

[22] Official Meat & Poultry Establishment Facilities and Equipment Requirements, Page 3. Operations Directive 111 September 1999, South Carolina Meat-Poultry Inspection Department, P.O. Box 102406, Columbia, SC 29224-2406

[23] Current Issues in Raw and RTE Products - Food Safety Magazine, December 1, 2003, Robert A. Savage. https://www.food-safety.com/articles/4784-current-issues-in-raw-and-rte-products

[24] *Ibid.* To be uploaded by the end of 2023

[25] Meat and Poultry Hazards and Controls Guide, Food Safety and Inspection Service United States Department of Agriculture, March 2018. https://www.fsis.usda.gov/sites/default/files/import/Meat_and_Poultry_Hazards_Controls_Guide_10042005.pdf

[26] Refer the chapter titled Design of Poultry Slaughterhouse - Material & Safety

[27] This critical appraisal of the square building mindset was originally included in Aptec's mid 2013 article titled "What Happened at Jilin Baoyuanfeng", referring to a fire that completely destroyed a sandwich panel poultry slaughterhouse in China and caused the death of 121 persons. At that time Aptec did not have access to a later revised version of the European Butchers' layout which forms the basis of figures 36 and 39. Because the square building analysis in this chapter primarily relates to that concept and is less of a criticism of other aspects of that layout, we have not bothered to edit the 2013 narrative.