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Handbook On Design & Operation Of Poultry Slaughterhouse – Chapter 3 – Layout, Geometry, Construction Methods & Environments

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Preface

The subject of design of slaughterhouse building has been divided into four chapters, namely Chapter 2 - Land & Location; Chapter 3 - Layout, Geometry, Construction Methods & Environments; Chapter 4 - Engineered Ventilation For Biosecurity & Efficiency; Chapter 5 - Materials & Safety: Lessons From Slaughterhouse Fires**.** Additionally some aspects of operation are covered in Chapter 8 where we discuss SOPs and emergency response.

This is the second of these chapters. FAQ and Glossary sections have been removed from individual chapters where they existed in the past and have been combined and re-compiled into Chapter 15 which is called Glossary of Technical Terms & Abbreviations. Meanwhile Chapter 14, called Processing Diagnostics, contains FAQs culled from earlier Chapters. Both 14 and 15 serve the entire Handbook.

This Chapter is aimed at two levels of readers, including some who may be consultants charged with the overall responsibility of preparing plot plans and plant layouts. If you are one of them, you would then yourself use a drafting program like AutoCAD for the job. Or you may be the designate plant or project manager, in which case you would take the help of a draftsman to do so and evaluate layout options prepared by him and compare them with concept layouts submitted by your vendors.

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 unable to use CAD, try a charting tool like Visio or even a paper sketch pencilled by yourself. Figure 10 shows how you may even use trimmed slips of paper. By dragging and positioning the slips to represent your ideas you would be taking the first step in visualizing the concepts for yourself and your team.

Preparation of a good layout plan involves observation of twenty-three rules and principles. Up to the end of section 1.1, we draw out the eight basic principles. In section 2 we list seven additional 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 put together. In section 4, after we have discussed construction styles in use, we list the remaining eight rules. Table 1 shows the location of all these rules and a brief statement on the principles that make up the contents of this Chapter.

Table 3 presents a compilation of machines used in the process, their salient features, rules associated with their use and the stage of design evolution that the machines are in at present. Chapters 9 to 12 expand on this theme, outlining poultry processing steps which we have divided into four departments. These are (1) killing, scalding & defeathering; (2) evisceration; (3) chilling & freezing and (4) portioning & deboning. Within these, we discuss machines, technology & design alternatives to help you make appropriate choices.

In figure 5 we list the principal steps involved in poultry processing, while figure 8 shows the schedules that different activities and departments need to follow over a 24 hour cycle, encouraging you with suitable logic, 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 section 5 we discuss examples of advanced process building layouts.

Example drawings from our past projects, spread over a quarter century of consulting work, have been used to illustrate these rules and principles. We believe that graphic examples are both convincing and memorable, but presenting large drawings on the A4 page format of this Handbook makes the task difficult. Therefore, when we complete the Handbook project, we promise to upload all the drawings in their natural sizes as a zipped file to overcome this problem. Meanwhile here is an index to the twenty-three rules and principles covered in this Chapter.

Table 1 Summary of rules and principles used for designing poultry slaughterhouses.

Rules and principles discussed in this Chapter	**Number of rules**	**Discussed in section**
Principles for designing a poultry slaughterhouse	8	1.1
Implementing them into the plot plan	7	2
Design rules related to available construction methods	8	4
Total of all rules discussed in this Chapter	**23**	1.1, 2, 4

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 the easy availability of slaughtered poultry. 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 2024 annual worldwide poultry meat consumption stood at 139-141 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 of just over 17 kilograms in 2023. The Indian consumption level is 6 kilograms per capita annum[1].

Figure 2 Scene from the 1992 film **Far And Away**, depicting an overhead conveyor track in a Boston poultry slaughterhouse. This film is about a west coast Irish lad who emigrated to USA in 1892 to seek a new life.

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. We have tried to trace the origins of automation, but have only come up with the picture in figure 2. At present, 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.

As processing capacities increased, human operators holding passive or pneumatic hand tools were unable to cope. So full automation becames necessary when **line speeds increased to such an extent that workers suited and willing to work at such paces for the duration of an entire shift became difficult to find, recruit and train**.

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

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 contrary, quality and hygiene may be impossible goals regardless of the level of automation if basic rules of layout design and SOP are not followed and periodic cleaning and maintenance is either ignored or performed sloppily.

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 mentioned there and Aptec’s views in respect of available level of automation at each stage are 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 done so, others are still evolving. In particular machinery for live bird arrival, stunning, evisceration and portioning & packing are still undergoing evolution.

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

1.1 Eight Design Principles To Follow 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 (a) potential of the available piece of land[a] and determines (b) the maximum line speed or plant capacity it can sustain in future[b] and (c) how much the market can bear and the limits of investment the entrepreneur can muster. One then draws out the boundaries of an initial plan[c] for a final line speed or capacity which is 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. In other words your first layout drawing should show two layouts - the initial and the final, and it should be evident from your work how the initial will grow and adapt itself to the final with natural progression, involving little or no dismantling, destruction or wastage.

Note the terms and phrases defined by a, b and c in the previous paragraph - potential of the available piece of land, market potential and investment potential. So the design process occurs in reverse: beginning with the final future capacity and arriving at the initial capacity. With this approach we determine the limits and then walk backwards to the present limits of availability of funds and market size. Had we not bothered to determine at the outset the limits of growth, then in the course of growing, we would have constructed buildings and structures haphazardly or at random and would need to break them or modify them too often.

Our twenty-three rules and principles are contained within this overall design philosophy. And as we progress through this Chapter, you will see how this design philosophy is present throughout the design process.

But first we will identify the first eight rules. Since they follow a logical sequence, we have listed them as steps in planning. As mentioned earlier, this sequence of steps is fairly universal – you may use them in any industry, not necessarily in poultry processing. Essentially, they are rules for industrial planning.

1.1.1 Step 1 – Determine The Nature Of The 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 allow you to bring in packing material and at the same time prevent the ingress of vermin etc into your process area together with all that packing material. In this case, *inter alia*, you need to ensure that the packing material day-store is near at hand but does not open directly into the process area.

And because you are discarding stuff in the slaughtering process (remember it is subtractive!) – stuff that carries bacteria and other contaminants, you need to hygienically, promptly and continuously remove them from the process area or run the risk of spread. The layout in this area must be designed for security against ingress of contaminants, vermin and bacteria.

So in **Step 1** you not only need to determine whether the **overall process** is additive or subtractive, but break the process down to determine whether the **sub-processes** are additive or subtractive and **cater to each accordingly.**

1.1.2 Step 2 - Identify Process Steps By Action & Machines To Suit

Unless you have studied and understood the process thoroughly, you will not be able to prepare a good layout plan. 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 (or at-present-irrelevant) 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 their own understanding of 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 we present in table 4. Or better still, copy and print the table, add a new column to the right and note down in it your own observations. Now this table contains all that the vendor **presents** and your own observations. The new column may also contain all that the vendor's literature **omits**.

Next, carefully read table 4. 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 specific process areas. Read inset 3 for details.

> 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 9 to 12, which are devoted to these processing departments. Chapters 9-12 are mainly aimed at the expert designer/consultant.
>
> ***Inset 3*** Different vendors follow different machine design approaches. Table 4 provides simplified information relating to choice of machines for each processing department. 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 seek help from experts. This is particularly important if you mix and match machines from different vendors.

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.

Table 4 **Steps in Poultry Processing, Required Machines & How They Impact Layout Design**

	Department/Action step	Comment	Technology status, cost[a]
1	**Lairage**	The ideal operation needs no lairage or possibly a very small lairage. Lairage size depends on plant capacity and travel time between commercial farm and slaughterhouse. Feed withdrawal is done at the farm: so this is not a design factor. Withdrawal time and relevance are discussed in Chapter 8. At the lairage you must cater to thirst and install fogging and fans. Use appropriate lighting level and colour.	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 by law or custom or simply chosen by you. Small & medium sized plants in South Asia use coop transport, electric stunning and linear hanging arrangements. Gas stunning & carousel hanging needs more space at this end. Include pneumatic neck shear for easy switching between *Halal* and *Jhatka* killing rituals. Refer Chapter 9 on arrival, killing & defeathering.	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 overhead conveyor line. Although an acceptable compromise at low line speeds, this is not acceptable at higher line speeds where cleaning of the line becomes inadequate with this compromise.	Modular. Not much evolution. Proportional.
3.2	**Water bath stunner**	If stunner is not used for religious reasons (e.g. Pakistan and Sri Lanka), strenuous wing flapping results in up to 25% wing damage. Islamic Fiqh Academy at Joga Bai, Jamia Nagar, Delhi supports	Not modular. Evolving. Choice of model largely

		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 your present line speed. Refer Chapter[2] 9 for types, functioning system, adjustment and configuration of machine.	unaffected by capacity, specially at small line speeds.
3.3	**Blood trough**	Use a stainless steel modular trough - design drawing can be provided by Aptec. A blood pump may be needed for line speeds in excess of 2000 BPH.	Modular, Proportional
3.4	**Jacuzzi or Jet Stream scalder**	Local machines under-perform in comparison with Jacuzzi or Jet Stream scalder. Steam scalding, promoted by Marel (now JBT), is a failed innovation. Steady temperature is the key to performance. Other design variations are (1) two or 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. Entire department layout depends on choice between even or odd number of passes in the scalder model that you choose.	Modular design, cost & expansion in steps of 1000 BPH. No design evolution.
3.5	**Feather plucker**	Local and Chinese machines tend to under-perform. A feather conveyor belt under the plucker bank is neither essential, nor a good idea – a floor gutter is enough to carry away feathers in the form of a slurry. Cylinder type pluckers with whip-like rubber fingers are not used in India. When comparing pluckers, compare number of fingers, not disks.	Modular - add machines of 1300 or 3000 BPH each. No evolution.
3.6	**Head-puller**	For efficient evisceration it is necessary to pull off, rather than cut off heads. Simple design – no evolution. Very small capacities use linear models, larger capacities (~3000+ BPH) use circular models.	Capacity limits for models.
3.7	**Hock or foot cutting**	Hock cutting (as opposed to foot 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. With separate killing and EV lines it exists at the end of the killing line.	No evolution. Must scrap this machine to switch to 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. Note Marel (now JBT) and Meyn unloaders are not inter-changeable due to shackle type.	No evolution.
3.9	**Hock processing**	Needed for peeling off yellow skin for export to China & SE Asia, use local machinery in small operations.	Add automation for higher line speeds.
3.10	**Chain & shackle washer**	Essential for product hygiene. More so in a combined line.	Suits all speeds.
3.11	**Orientation**	Orientation and hall width 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 pass and three pass scalding.	-
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 rehangs and takes over the function of a hock-cutter.	Modular, with proportional cost in 2000 BPH steps.
4.2	**Overhead EV line conveyor** with shackles, drive and lubrication system	Choose between a combined line (for <2000 BPH) or a separate EV line for higher capacities. Shackle pitch of 12" & 6" are possible. See note on precautions for placement and configuration of line machines and total overhead chain length when using 12" shackle pitch.	Modular. Not much evolution. Proportional.
4.3	**Evisceration trough or belt.**	In semi-automatic evisceration the actions can be done with 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**	Do not cut the vent manually. A pneumatic tool is essential for cutting around cloaca without damaging the bursa and spilling the contents of the gut into the body cavity.	Not modular. To expand add machines, resulting in proportionality. No evolution.
4.4.2	**Pneumatic, vacuum aided lung pistol**	Pneumatic tool for removal of lungs and tissue debris from the body cavity. Manual removal lowers product shelf life.	
4.4.3	**Gizzard peeling**	Removes the inner horny yellow skin of the gizzard. Not easy to do without this machine.	
4.4.4	**Pneumatic neck cutting scissors**	Used only where the customer wants carcasses with neck off as in European style griller. Not used in India for this application.	
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[3]. Then there is a partial level of 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.	Meyn offers a new, efficient & cheaper design
4.5.2	**Automatic crop removal machine**	Automatic evisceration machines do a more thorough job than manually possible. Aptec recommends it from 2000 BPH upwards.	No evolution.
4.5.3	**Automatic vent drill machine**	Not to be confused with pneumatic vent drill. It does a more thorough job than manually possible. Aptec recommends it from 4000 BPH onwards.	No evolution. Combined action models are unsatisfactory.
4.5.4	**Automatic opening machine**	Different models to suit different processing styles beyond 4000 BPH. Models for different opening actions are available.	
4.5.5	**Automatic evisceration machine**	Two styles exist – spoon type and hinged type each with different performance result and yield. Different sizes to suit different line speeds. Examine carefully the vendor's guarantee for bird size variation.	Not much evolution.
4.5.6	**Giblet harvesting machine**	Several automatic and semi-automatic models available from all vendors. Running cost & yield influenced by farming method.	Not much evolution.
4.5.7	**Automatic neck machines**	Models for processing carcasses with neck and neck skin removal are available. Not used in India because neck-on is acceptable here.	
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 static ice slush tanks. Local machines generally ignore counter-current flow and give poorer results. See Chapter 11. Available in steps of 1000 BPH at 1600, 2100mm or higher dia.	Modular. Cost is almost proportional.
5.2	**Air chilling**	Less cost-effective than spin chilling. Not popular in India yet. See Chapter 11 for comparison of air & water chilling	Technology is evolving.
5.3	**Dewatering or dripping system**	Small plants use locally made drip racks or tables, progressing to spin extractors. When weigh-line is installed, Aptec prefers extending its length for drip-dewatering of carcasses.	Modular. Mature. Proportional.
6	**Weighing and Grading Department**		
6.1	**Rehang conveyor**	Can be locally sourced. Factor one person for every 2000 BPH. It is possible to configure this belt for 'B' grading.	Modular. Proportional. High level of evolution.
6.2	**Table-top weighing machines**	Electronic table-top scales for manual weighing & grading of portions, whole carcasses, and tray packs.	
6.3	**Automatic weighing & grading line or machine**	Computerized, highly accurate on-line weighing/grading for batching into weight categories (8 to 32). Possible to perform less accurate batching at lower investment with grading belts.	
7	**Secondary Processing & 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 larger capacity plants, each machine suits ~800 BPH.	
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. Extendable.	
7.5	**Japanese cut-up line/J shackle line**	A larger and more efficient system than the cone deboner for capacities 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 often offsets their advantage but the situation is poised to change. At higher capacities, combination of **compact cut-up** machine with cone deboner & Japanese cut-up lines is most suitable for India. See Chapter 12 for discussion on the subject.	Partly modular, Evolving, Not proportional.
7.7	**Packing machines**	A large variety of tray-packers available locally.	Proportional.
8	**Auxiliaries**		
8.1	**Offal handling section**	Processing waste removal as slurry via floor-gutter system and gantry mounted pipeline to rendering building is suitable for India. Neither slurry pump nor bow screen filter available locally. Manual handling of offal is unhygienic. Chapter 13 for complete coverage.	Not modular.

8.2	**Coop/Crate washing section**	Two coop sizes are used and match locally made coop washing machines. Automatic washing reduces manpower and ensures consistent and hygienic operations. Chapter 7 for contamination from coops unless they are thoroughly disinfected, washed and fully dried.	Not modular. Capacity based on crates/hour.
8.3	**Steel superstructure**	Required for suspension of overhead conveyors. Typically made by bolting together dip-galvanized '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

[a] This column provides information about technology status in the following manner:

<u>Mature/evolving</u> 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. You must make note of this in terms of changes in space requirement, processing parameters etc in your layout plans. Where it says **Strong evolution**, you must study 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 simple additive 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 etc tend to be non-modular.

Proportional whether modification to meet your objective of increasing capacity raises cost roughly in proportion with that added capacity.

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 these bundled layouts. There each machine footprint has a number that links it to a legend tabulated in the drawing.

[b] These Chapter numbers refer to the Handbook which may be downloaded free of cost from the Aptec website.

c **Using 12" shackle pitch with in-line EV machines.** Two precautions have to be exercised. (trolley pitch remains at standard 6" pitch).

Since your line has trolleys 6" apart from each other and your shackles are 12" apart from each other (i. e. on alternate trolleys), your overhead line must contain an **<u>EVEN</u>** number of trolleys. (Master wheels of all EV machines in the poultry industry, regardless of the vendor are exactly divisible an even integer times by 6" or 152.4mm, without leaving a significant remainder).

Ensure that the unit on each EV machine engages with the trolley which holds a shackle. If it does not, then your EV machine(s) will appear to work normally, with all moving parts performing a pantomime, but never engaging with any carcass! To correct this error you need to loosen the line tensioner and then mate the correct trolley on the line EV machine(s) to comply with this requirement. If there are two or more automatic machines, ensure that all of them mate. You may need to shift machines slightly on the overhead construction to do so. Re-tighten the line tensioner after doing this.

It should be evident to you by now why some vendors insist that their customers always buy their EV machines with units at 6" pitch from the start, even when a prudent and buyer-friendly solution lies in offering a 12"/6" combination design in phase 1 of some low capacity plants. These vendors were too lazy or ignorant and never figured out the subtleties of the 12"/6" combination design.

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 designers, plant managers and supervisors with practical hands-on 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 4 for reasons of brevity and simplicity.

Table 5	**Automation Of Evisceration In India (circa 2022)**	
	Level of automation	**Operating and planned plants in India**
1	Plants with 4 or more machines and 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 the developing world, i.e. in Asia and Africa*)

2	Plants with 1-3 automatic machines	Approximately 17 plants. You will find them listed in table 1, part A of a contemporary Industry Report on the Aptec website. They are the ones with 1300-3000 BPH capacities omitted from the above list and made by Baader-Linco, Marel, or Meyn.
3	Plants with no automatic machine at all	You will find them in all remaining plants in table 1, part A, of a contemporary Industry Report. This includes plants supplied by Bayle & indigenous fabricators.

* 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 addition it reduces the functioning time for each functional unit within the machine.

** Seven actions which a fully automatic plant needs to perform in India are: (1) Vent drilling, (2) Opening, (3) Evisceration, (4) Giblet harvesting, (5) Cropping, (6) Final inspection (lung removal) & (7) Inside-outside bird washing. Neck breaking & neck skin trimming machines are not relevant to processing for the Indian market because carcasses are sold with necks attached.

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 now to allocate some physical space in your layout for possible processing variations that remain contingent at present upon indeterminate technological or consumer behaviour factors, or local laws, but may gain importance through the lifetime of your proposed plant.

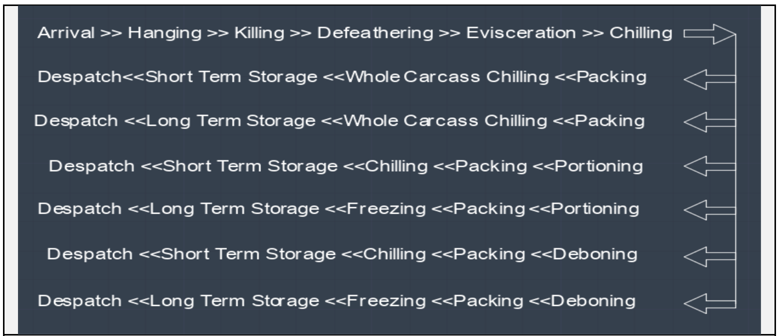


Figure 6 Determine whether the progression of individual process steps follow a linear or branched pattern. The above steps can be further subdivided – once you create a mental image of the actions needed to carry them out. You will find that the pattern should determine the physical layout and allocation of spaces for the individual process steps. Then note why the layout in figure 7, being essentially linear, falls woefully short of the ideal.

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. Meanwhile you are always welcome to e-mail us for help.

While you 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 in which the product cannot be washed or disinfected any more! This is the irony of the pejorative associated with the phrase “un-touched by human hands”!

Automation of evisceration becomes most important at some stage of your expansion. 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 because this feature either permits it to flow in a pipeline to be conveyed or carted through the production process, moving right or left, up or down and forward as it undergoes conversion into finished products. Only if it is a fluid or granular, can we safely choose the plot of land in figure 7, with its unusual aspect ratio.

On the other hand if your raw material is neither fluid nor 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 branches cannot be sped up or slowed down or placed on hold for any length of time. Towards the finishing stages in the process you will need to decide what portion of your poultry will be frozen and what will be sold fresh-chilled. This branching in itself, will completely negate the simplistic linear process-flow pattern.

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 under a week, provided the cold chain from the processing plant to the consumer's refrigerator is intact. Read Chapter 11, for more details on frozen versus fresh chilled poultry and Chapter 2, for solutions aimed at increasing the shelf life of fresh chilled poultry.

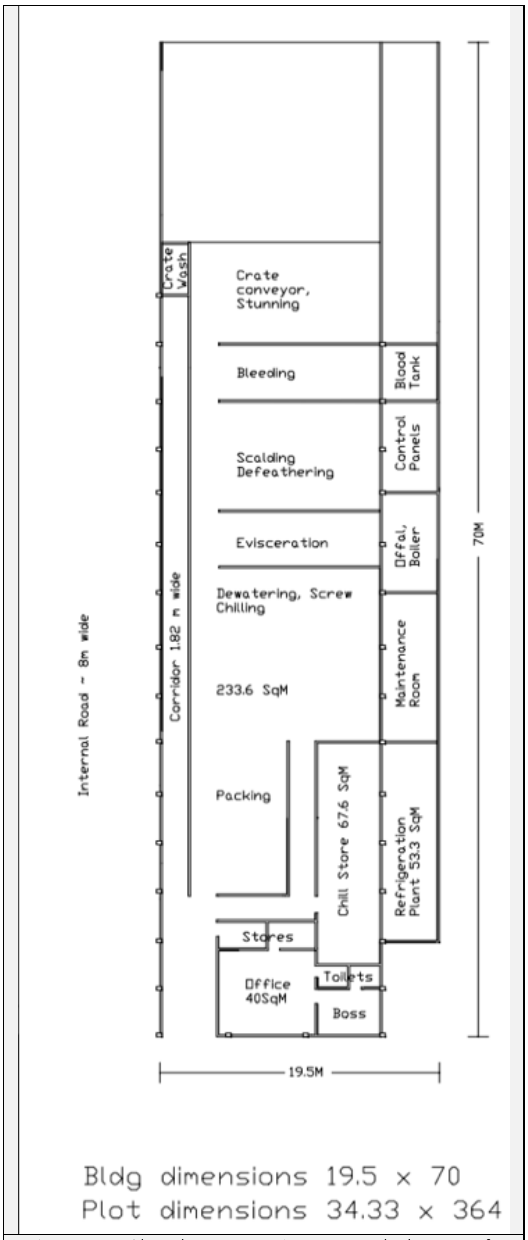


Figure 7 Showing an 1:3.5 aspect-ratio layout of a 1000 BPH poultry slaughterhouse designed for an 1:10 aspect ratio plot of land. This design owes its outlandish features to the then chief of the company that built it, and who chose the plot of land with its extraordinary aspect ratio and designed the layout himself, sometime in 2001.

Meanwhile for all these consumer trends, your effort has to concentrate on processing poultry for the fresh chilled market rapidly 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 getting frittered away in your plant and in transit on the road. With the simplistic linear process-flow shown in figure 7 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 7 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 short this plan ignored the design philosophy we are explaining in this Chapter.

As a result, 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 eventually purchased an adjacent plot of land and on the wider, consolidated site, a new plant was constructed to replace the existing one. This time around, the layout was not drawn by a lay person.

1.1.4 Step 4 - Identify Special Process Features

In a poultry slaughterhouse, arrival of live birds is the dirtiest step. From here on, we progressively move into cleaner and cleaner steps. Final hygiene and cleanliness of the product is essential to shelf life and public health. So, to maximise hygiene, the dirtiest areas are always placed farthest from the cleanest areas. **(1) Here we have stated the first special feature of poultry processing** – a good design incorporates a gradient of cleanliness – from the dirtiest to the cleanest and the sequence must be expressed in terms of physical placement in your layout. Also, for aesthetic reasons, you must try to place the dirtiest end farthest from the access road to your premises.

Since the shelf life of chilled poultry is short you need to move it 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 of poultry processing.**

Figure 8 A toll plaza. Notice how the number of lanes multiply several-fold to reduce traffic hold-up. Work flow in your processing lineup follows similar rules.

How does freezing stabilize prices? Poultry is a perishable product – 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. So the cost per live bird rises because more input went into each bird. Read Chapter 11 to understand how seriously increase in live weight impacts the size, capacity and space and investment needs of the primary chilling department and read section 1.1.8 of this Chapter to understand how this also impacts the grid size and grid choice in column positioning within the slaughterhouse. We can conclude that from time to time because of live bird price cycles, birds tend to get heavier and this impacts chilling time of carcasses, which in turn impacts the space requirement in the chilling department. **(3) This is the third special feature of poultry processing.**
In order for the farming and slaughtering activities to match, there should be cooperation and feedback 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 cycles of gluts and shortages to block competition in broiler breeding.

Although the poultry processor is victim to these price swings, nevertheless he uses these swings to outsmart the wet market which is his strongest competitor. When live bird prices crash he runs his slaughterhouse at higher speeds and for longer hours, to process more and freeze the surplus. When live bird prices rise next time, he liquidates his frozen stock and makes an extra buck. Since the wet market operator cannot freeze poultry, he cannot stock it.

But the processor cannot be censured for taking advantage over his wet market competitor, because wet market operators are faceless, their produce is not taxed by the government whereas the processor, being a registered entity, has to pay GST. So if as an organised sector processor you fail to add stamina to your plant designs to take advantage of price gluts, you have failed to outsmart the wet market.

What does addition of stamina entail? It calls for over-design of the chilling and freezing departments. The first burden is on account of larger individual bird sizes (we called this an **extrinsic** factor in Chapter 11). The second burden that we place simultaneously on the plant is the owner's propensity to process more birds per hour and run his plant longer hours. Both these factors collectively place a premium on space in the chilling and freezing departments. (**4) The owner's need to run his plant hard from time to time is the fourth special feature of poultry processing.**

What other design features in the plant are affected by the fourth special feature of poultry processing? Because he wants to run his plant at the highest designed line speed, possibly higher if he can, with your design you must help the owner 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 chilled water and flake ice machines 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.

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 suddenly widen the surface so much? Simply because they realize that the traffic will slow down at the toll gate, so, to reduce obstruction to 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 lengths 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 and the number of products also increases. 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 because of a long list of stock keeping units or SKU[2]s. How do we solve this in terms of layout planning. We simply widen the traffic stream in these steps, just like a highway engineer does. By doing so we cater to some of the special features of poultry processing.

But there are space restrictions in the way of your planning. 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 and rooms along its sides, (additive-ness or subtractive-ness of the process comes into play!). These service rooms cannot easily be relocated. They 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 of this Chapter 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 this section of the building in the direction of product flow – not at right angle to it. But at the outset you need to ***determine the planned width of the truss-roof building*** that houses the Extrudable Block and maintain that planned width as a permanent feature or the ***extruded width of your design***. And as you expand, this truss roof building extrudes in the direction of product flow. Figures 14 and 15 show this expanded width. You will realise with experience that every strategy for expansion other than widening followed by extrusion will achieve sub-optimal results.

Why did we add the phrase "truss-roof building" as a feature of the extrudable block? Because this block needs a low ambient temperature, typically +12°C or lower and must therefore have thermal insulation and refrigeration of ambient air. This makes the building lighter to construct and therefore allows one to use the cheaper truss roof feature. We will return to these features in a later section on construction methods.
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 Chapter 4 on engineered ventilation for biosecurity, that any structural modification of components within this area seriously affects the air flow and hence hygiene and product quality. We shall use the phrase **'Inflexible Block'** to characterize this set of workspaces.

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 as the plant capacity grows. 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 4 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, (covered in detail in Chapter 9). This may become necessary when you change your stunning system, for instance. You need more space for such a change. 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. If you read Chapter 11 of this Handbook, you will be able to understand how. To sum up, by division of the plant into two conceptually different blocks with special requirements, we have catered substantially to some special features of poultry processing.

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

Ask yourself, is it possible or advisable to arrange the process sub-pathways of figure 6 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 6 in parallel, starting in the first and extending into the second shift. If it is possible to do the latter, you 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 your assets.

At this point let us ask how 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 of assets. Let the installed refrigeration capacity be 500 tonnes (500 TR or 1758 kW of refrigeration capacity) and the installed electrical 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 all 24 hours in 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 entirely move 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.

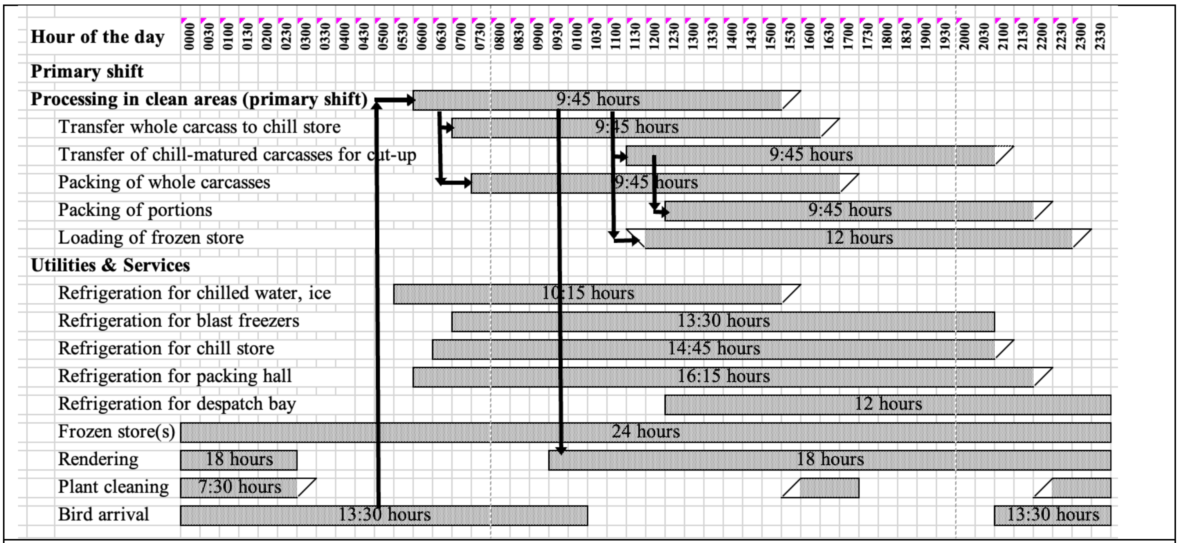


Figure 9 Desirable staggering of work schedule at a typical poultry slaughterhouse. This is how the process looks when you break out of the shift operation mental framework.

Figure 9 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 in the poultry slaughterhouse.

Of course, your preferred schedule will need adaptation to suit your specific project. For instance, here the primary shift begins at 0600 hrs – you may choose a different starting 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 in farm sheds. Read more on harvesting, transport and feed withdrawal schedule and implications of SOP in Chapter 7. The duration would also depend in your case on the distance birds need to be transported. So the schedule in figure 9 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.

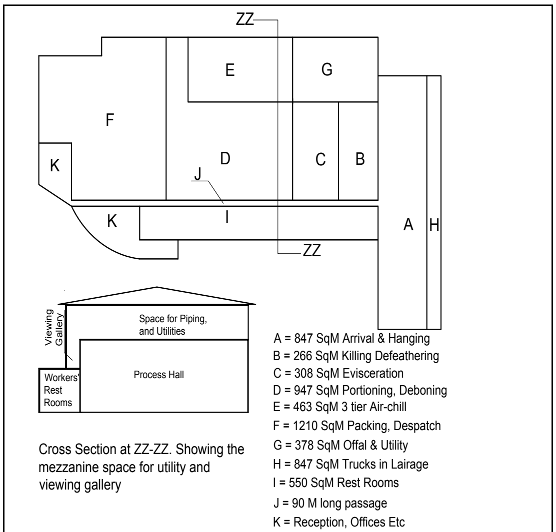


Figure 10 Space allocation within a 9000 BPH processing plant in north-central Europe. 'A' shows arrival and lairage and 'H' is the road that trucks follow into this area. Both A and H are under a common roof so as to function in inclement weather. Such a closed design may work well in cold weather, but will fail miserably in tropical lands because it reduces natural ventilation and cooling. Note also how the outline of the building departs completely from the square building paradigm even in a heavy snowfall area where conventional wisdom would have favoured a square building design.

Once you have finalised the schedule, your refrigeration vendor can use it to effectively plan his equipment configuration and also specify standby capabilities to take care of breakdowns. To plan your refrigeration capacities use table 36 in Chapter 11. Your HR department caters to the manpower needs, recruitment and roster and plan overtime payments using the work schedule derived from figure 9. Here, with the creation of a 24 hour work-flow within the plant we have rid ourselves of the shift operation paradigm and have also catered to some of the special features of poultry processing.

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, but not by expanding the hourly capacity of the plant itself. 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 local labour laws and coordination with commercial farms.

Figure 11 This picture[3] best illustrates the process of assembling blocks together to prepare both a plot plan and a process building layout.

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[4]. 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 attached at 12” pitch and the cropping machine and inside-outside washing machine will also have half the total number of **operational units**, to suit a shackle pitch of 12”.

Later, when you progress to 6000 BPH (or even to 4000 BPH), you will add extra shackles to reach a shackle pitch of 6” in the evisceration overhead conveyor line. To match the 6” shackle pitch you will also mount extra **operational units** (or just ‘units’, in the parlance of the vendors) in both machines to match. Because the capacity of automatic evisceration machines corresponds to the live bird numbers to be processed, all such machines manufactured by Meyn, Marel and Baader-Linco, are designed for 6” shackle pitch for up to 15,000 BPH[5] and for each such machine, the capacity can be halved by using a 12” pitch. In other words the maximum number of units all such machines can accommodate is an even number: not an odd number.

The delivered machine capacity depends on the number of units mounted along the circumference of its master-wheel. What size of wheels do you use when you mount these units to operate with a 6” shackle pitch? This is how it is done. 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 exact **even** number of units. Wheels which can accommodate an exact odd number of units at 6” pitch are of no use at all. Now your machine models are built with master-wheels of such exactly-divisible-by-even-number-of-units circumferences. For instance, the smallest Maestro eviscerator model has 12 units, and the biggest model has 28 units.

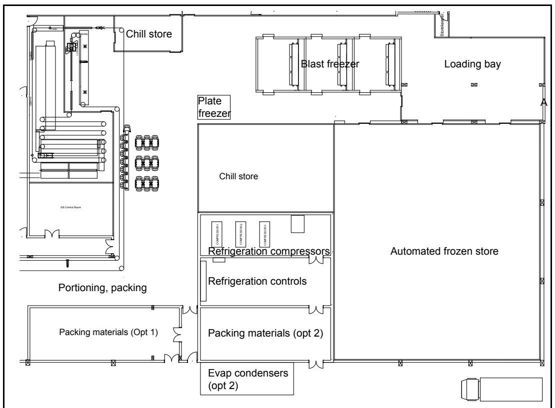


Figure 12 This layout, for expansion of an existing facility, shows two options for position of packing material store and evaporative condensers. The client backed option 2 in which the former almost blocks the escape route for workers in the refrigeration plant room in the event of a fire. This choice reduced the piping cost but close clustering of all cold areas blocked escape routes on three sides, adding to fire risk. Additionally the packing material store with quantities of combustible materials worsens the fire hazard.

Although we mentioned earlier that we planned to install three automatic machines, so far we only talked of the cropping machine and inside-outside bird washing machine above. The third automatic machine is off-line. It is the set of giblet processing machines[6] which can operate up to 3000 BPH. Look at table 4 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 (accounting for 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. In doing this it helps to refer table 1 in Chapter 8, which contains rules regarding space that you must leave around machines. Figure 11 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.

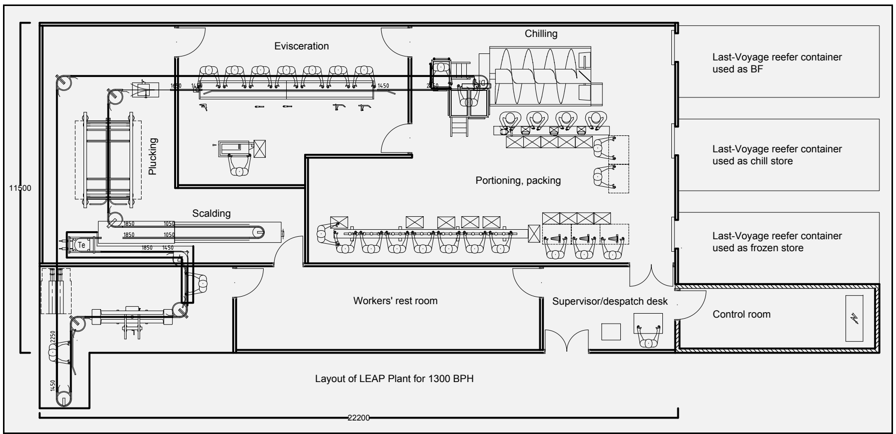


Figure 13 This is a slightly modified representation of the original LEAP layout for a 1500 BPH plant designed by the author in 2011. It is built on a tiny plinth of 255 SqM which is later, on expansion, incorporated into the floor of a larger plant. Except for the electrical control room, walls are 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. The initial 2011 design drawn here was for 1300 BPH. Later Meyn made some modifications in the Jet Stream scalder which took its capacity up to 1500 BPH, so this layout now delivers 1500 BPH. This concept ought to work equally well for Marel and Baader-Linco: capacities being dependent on their smallest two-pass scalder models.

You are now nearly ready to prepare a draft plot plan and the interior of your process building. And to do so you must observe other rules, because besides the eight rules that you have followed so far, there are six new 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 the latter we need to study them in the context of plot plan and construction methods.

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 7. Within that plot of land, taking note of the position of the access road, (and of the cardinal directions if you have to comply with halal rules), you draw simple blocks denoting the main process building and various utility, service, offsite components etc 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. Use these dimensions from these layouts as a guide. Once you have done so, use these following principal rules for assembling functional blocks in a plot plan. You may use the method described in figure 11.

There are seven rules or principles for making a satisfactory plot plan. Here they are:

1) **Leave sufficient space** for making a lagoon for storing and **treating waste-water**[7]. You will find this topic covered in Chapter 13 of this Handbook, but essentially, because a zero discharge rule

applies in India, there cannot be any thumb-rule for the size of land area required for this. You need to read Chapter 2 to understand the reasons why no one except your local pollution control board can help in this matter.

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 and incorrect choice of materials. 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 and pass through it. Figure 12 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. Refer Chapter 8, on SOPs and preparation for emergency response in a poultry slaughterhouse and Chapter 5 for a case study about what happens when you neglect safety rules and common sense when designing and constructing a poultry slaughterhouse.

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. Read about the physiology of facultative respiration in Chapter 7, about this particular bacterium in Chapter 5 and about rationale for a gantry between buildings in Chapter 13.

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 immersion chilling block. We have called this the **Inflexible Block**. You must design all spaces within this block 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 9 which covers stunning to understand this.

   Likewise read sections 1.1.5 and 3 of this Chapter to understand the methods 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 total 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 plot of land to an extension of this grid**. All columns must stay on the grid. If you use varying grid spacing, mistakes are invariably going to occur during construction: 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. Errors 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 14, 31 and 35 to learn how this objective is achieved.

6) Always **begin a layout drawing for the final capacity**. Make a copy of it. Then, using the equipment placement and position of walls and partitions drawn to suit it, fit the initial capacity machines into that copy. 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 final and initial versions of the drawing, with the initial capacity layout shown in detail and the final capacity layout embedded in the sheet 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.

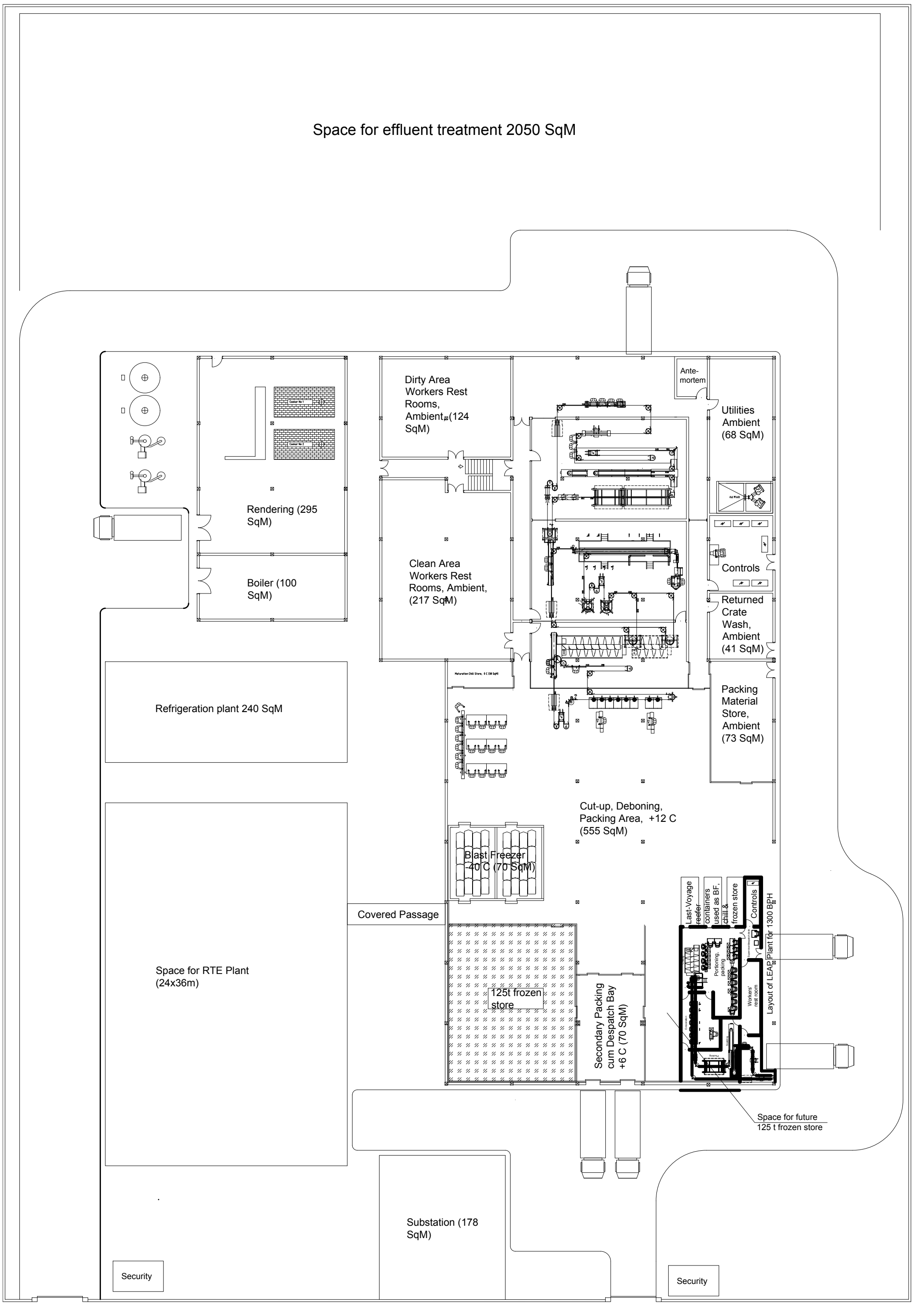


Figure 14 Plot plan showing a final 4000 BPH plant layout which figure 13 machinery will be upgraded into. Within the truss roof area of this layout you can see the initial 1500 BPH capacity layout. This drawing should give you an idea about what a vast quantity of civil construction can be postponed to phase 2 if you begin with 1500 BPH LEAP layout concept.

7) When you release a drawing for construction **always ensure that your drawings specifically carry the instruction – "released for construction at site"** or a similar message expressed clearly. Construction must never begin at the site unless the vendor's or architect's or consultant's drawing carries this notice. Very often drawings made by young draftsmen who have no site experience are taken up directly for construction without noting that these were only **concept** drawings.

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 attend to construction methods now.

2.2 Making A Simple Plot Plan

We will now use the rules we have learnt for making our first plot plan, with the smallest possible initial capacity of 1500[8] BPH LEAP plant. To do so, 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 14. 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 13.

But if your initial process building resembles figure 14, you will be locking up a lot of funds in it. You will certainly make it suitable for 4000 BPH, but much of that investment will remain unused and generate no revenue throughout the period that you run at the initial 1500 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 13. 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 in his country 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 rating, 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. So even though they may have been retired, there is normally a lot of useful life left in them.

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 and for producing ice.

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 cam-lock type 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 roof and false ceiling design of the final building.

We now ask ourselves, have we followed the rules of a good design philosophy in performing this task? Not quite. We have flouted some rules. In making the 1500 BPH plan ultra-compact, we have made the process flow in a semi-circular path 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 of following a circular path. 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 if we did, were we justified in doing so, considering the enormous reduction in initial investment that we achieved

3 Construction Methods

Two distinct construction styles are popular internationally. The choice should depend on relative cost, functionality, safety and local environment conducive to the chosen 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 Chapter 5. 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 and functionality. 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 34 and 35 which show the plan and elevation of the same 6000 BPH capacity building. In figure 34 the extents of Inflexible Block and Extrudable block have been identified.

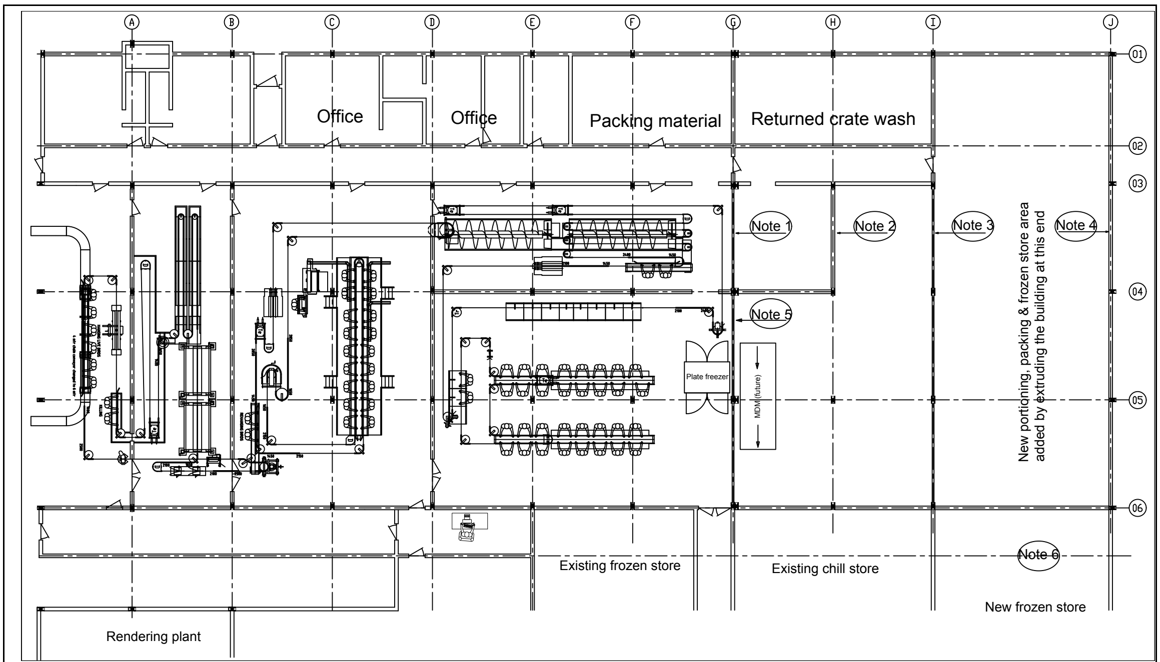


Figure 15 How extruding part of the building helps you implement expansion. Note 1, 4 & 5 indicates cam-lock panel walls that can be relocated to expand the enclosed spaces. Note 2 indicates repositioned cam-lock panel shown as Note 1, while Note 3 indicates the next alignment it will be relocated to. Note 6 shows how a new frozen store has been created to serve this stage of plant expansion.

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. We are confident he will change his mind when his business shows off its paces. How does the Extrudable Block 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 34 and 35. Space exists in the live bird hanging area to accommodate more workers and 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. This is achieved by showing a wide enough bleeding trough version where an expanded overhead bleeding track may be placed. 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 dotted lines do not show clearly – blank spaces do show clearly, however.

We will take one more example to illustrate this point. Look at figure 36 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 suit as the capacity grows. But unlike the Inflexible Block, here we are able to add to the building by a process of **extrusion** of the building itself.

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. Now let us examine how this block is extruded.

Read notes 1 through 6 in figure 15 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 up to gridline J. 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 only up to gridline G. For expanding the plant **even while it continued operating**, a new 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.

But this was not all. 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 but lies beyond gridline J.

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 legacy factors, 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 legacy 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. Here a given thickness of reinforced concrete slab is poured onto the steel deck to form a composite roof slab.

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 has made this event into a case study presented in Chapter 5. It deals with 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 this 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 Chapter 5 on materials & safety.

Figure 16 Picture on top 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 the project where this picture was taken, a highly experienced French contractor was using inexperienced Sri Lankan workers for construction. The workmanship reflects not upon the skill and experience of the French contractor but the inexperience of the Sri Lankan workers.

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 learning why they were developed we will appreciate how inappropriate they 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 one plenty of space on the ground within the confines of the steel framework of the building. In this way when decks are constructed, the stockyard area always remains accessible.

With such a roof slab (or floor slab, by turn) we have two structural components forming it – the steel decking which started out as a scaffolding and the RCC slab poured over it. 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 in 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 during the construction phase. 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. Drawing of embedded ceiling anchor appears in Chapter 9.

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 social gathering places and wedding and banquet halls nowadays – more so in the West. Construction with sandwich panels 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 cuboid-shaped sheeting.

Table 17	**Summary of Features - Performances And Properties**	
Feature	**Hybrid Building Style**	**Sandwich Panel Building Style**
Cost	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 roof slab buildings do. This is probably because of the easy availability of workers skilled for the latter.	
Speed of construction	Panel buildings can go up more rapidly provided plans do not change during construction and appropriate construction equipment is available.	
Planning, standardization	Very difficult to standardize across construction jobs. Difficult to sell turnkey design service for an Indian construction contract from a central overseas head office.	One can standardize across construction jobs. Easy to sell design service from a central overseas head office.
Columns	Because RCC roof slab is heavy, you need a close grid of columns (typically RCC) in the 6x5 to 8x7 metres ballpark.	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.
Precipitation proofing	Meticulous attention and additional features needed to prevent leakage. This kind of roof is unacceptable in areas with heavy snowfall.	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.
Skillset of builders	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, acquiring necessary skills, and may be lured back. 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 is true in the developed world.	
Access to special equipment		
Life of building	Thirty years for whole building	10-12 years for panels. 30 years for steel frame
Fire safety	High	Low
Working space & suspension of superstructure	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.	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 and 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 hauled and fed into the screw chiller.
Vermin proofing	Very high.	Poor in areas with low skillset and where there is absence of appropriate construction equipment.
Design flexibility	Good	Poor. Because the architect is restricted to the use of a cubic structure or a square building paradigm.

Expandability	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.

When you build exclusively with sandwich panels you lay PUR/PIR pre-formed sheets 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 29 and its cross section is shown in figure 30.

In table 17 we have summarized the salient features of different construction styles in use and compared their relative merits. Table 18 shows which style best serves which offsite and utility building. You will discover for yourself as we proceed, that the best choice 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 the sturdy, load bearing qualities of RCC roof slab in combination with brick walls as standard and suitable for construction of poultry slaughterhouses in India. Aptec has compiled a set of specifications for all features of such slaughterhouses. This is available in table 19.

3.2.3 Hybrid Construction

As mentioned above, the preferred design involves a combination of brick walls and RCC roof slab 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 in the Inflexible Block.

Table 18 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 plot of land. Minimise distance to central refrigeration plant to reduce trench-buried LT cable cost.
Effluent treatment plant	According to the vendor's specs.	Preferably at the back of the premises. Read rules for treated wastewater discharge in India in Chapter 2.

3.3 Other Buildings

Two distinct plans and construction styles are in use for rendering and have been covered with examples in Chapter 13 on rendering design options. 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[9]. 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[10]. Instead of individually discussing other utility and service buildings which form part of the plot plan, we have coverd them collectively in table 18. Aptec recommends the above 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 covered in table 17.

3.4 Aptec's Recommended Construction Specifications

	Arrival, lairage, hanging area	Defeathering, EV, spin chilling	Packing & portioning	Cartoning or pallet wrapping, ante room, despatch bay	Blast or spiral freezer, chill & frozen stores	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 or drop 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. This is to match the plant floor with standard truck deck height. All foundations are of RCC

Temperature for all areas ambient except: portioning & packing areas +12°C, chill store -1 to +4°C; frozen store -18°C, blast freezer -40°C, despatch bay +8°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. Refer figure 14 in Chapter 13 for details

= Refer Chapter 5, table 45 for safety rules concerning all sandwich panel constructions, including specifications for doors, windows, passages, signages, etc

^ = For adequate RCC ceiling slab and beam heights to permit the construction of a viewing gallery see figure 19 for minimum heights

Table 19 Showing Aptec's recommended specifications for all buildings in a poultry slaughterhouse

4 Other Design Factors

4.1 Are You Locating In Industrial Estate Or Greenfield?

We have covered this topic in Chapter 2. 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 Chapter 2 to familiarise yourself with the arguments we make in favour of greenfield properties for poultry slaughterhouses in India.

4.2 Must You Combine The Entire Process Under One Roof?

We have covered this topic in detail in Chapter 2. 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 water requirement and need for heavy investment in power, waste-water treatment and refrigeration and came up with the **Hub and Spoke Concept.**

Some entrepreneurs may wish to combine poultry slaughter with further processing of poultry meat to produce ready to eat (RTE) products on the same premises. There are rules for combining such activities in the same premises. These rules have been discussed with an example layout in section 5.3 of this Chapter.

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 your 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.

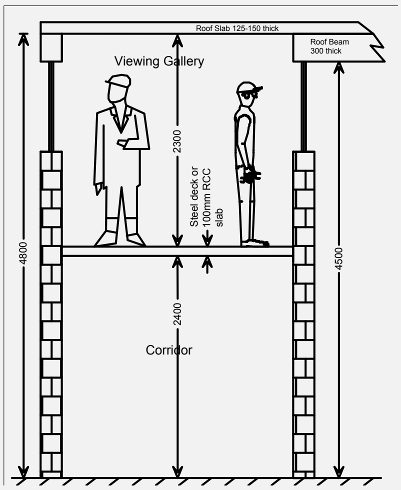


Figure 20 Section through an appropriately dimensioned viewing gallery

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 20. In figures 31 and 33 you can see the viewing gallery over the Inflexible Block and extended into the Extrudable Block.

4.4 Will You Award The 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. The majority of foreign turnkey engineering companies operate in many countries and it is difficult for them to have information on all 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. With this in mind, Aptec has a working arrangement with Orkay Constech India Private Limited of India with whose participation the best of both approaches is available under comprehensive technical consultancy from Aptec.

Figure 21 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; appropriate, because the mummified state is permanent.

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. In any event, machines need regular maintenance which requires access space around them. For all these reasons layouts should not pack machines tightly, leaving inadequate space for repair, maintenance, removal or replacement. Therefore plant design must always incorporate sufficient space around machines. This is also a recommended standard according to The Equipment Design Task Force (EDTF), about which you can read in Chapter 8, table 1.

Besides, an industrial plant is not a consumer appliance like a mobile phone. You do not trade it in for the next model every three years. Unlike the popular materialistic consumerism design trend of our times, which deliberately incorporates built-in obsolescence in consumer durables, plants are expected to last long and lend themselves to modification and expansion over their lifetime. Machine lifetimes may stretch over several decades. To appreciate why industrial design must adopt a different design philosophy than that for consumer durables, let us examine which are the essential ways industrial plants differ from consumer appliances.

To set up a slaughterhouse, a brick and mortar building of appropriate dimensions is constructed, finished and then individual machines are dragged into position and joined together with an overhead conveyor system. Corridors must be built through which machines may be brought in. Also these same corridors provide the means to remove obsolete machines for replacement. By careful planning these same corridor spaces may also serve as routes for entry and exit of workers and for emergency evacuation.

However, if we build with sandwich panels, 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 a piece of candy into an already formed foil wrapping. In the context of industrial machinery such an approach assumes that machines are just another set of Egyptian mummies that will exhibit no change for all time to come. Sandwich panel buildings therefore serve machines no better than a sarcophagus serves a mummy.

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. It richly deserved the remark that it received – that the designer surely possessed all the skills of a budding Egyptian embalmer of mummies!

This author went on to explain 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 spaces in each department, such an eventuality could be easily handled. 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 more spacious design to its 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. This team typically consists of greenhorns who may be skilled at computer-aided drafting, but unfamiliar with the business of slaughtering poultry and inexperienced in industrial 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-draftsmen teams lack the wisdom of permitting an increase in capital cost to reduce operating costs in order to highlight the positive feature of their designing skill.

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, uncontrollable, and sometimes disastrous outcomes for a business.

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

Sarcophagus Example 1 Figure 22 shows the layout designed by a vendor’s young AutoCAD expert for an Indian customer’s 4000/8000 BPH slaughterhouse. In this 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.

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 orient properly?

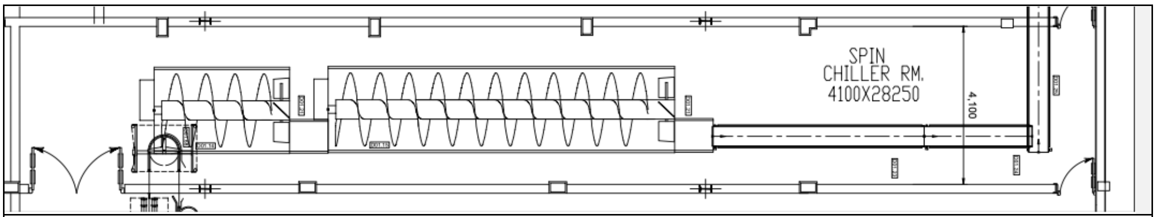


Figure 22 Vendor drawn layout supplied to a customer for placement of screw chillers of 2100 diameter and 3500 + 9000 lengths inside their 4100 wide **"sarcophagus-style"** hall formed by 250mm brick walls.

And if you did somehow manage to turn them, how would you make two chillers of 2100 width slide past each other in a 4100 wide hall? Let us reconstruct the design steps. The lad who drew this layout first drew the machine layout and then placed a "wrapping" of sandwich panels around the machines to outline the departments. And the lad further assumed that the plant would "naturally" be constructed exactly in that sequence of steps he imagined! Obviously this is what you get when inexperienced draftsmen plan slaughterhouses merely on the strength of their skills in in the use of CAD. This is like expecting anyone familiar with the English alphabet to break out in a spontaneous recitation of Shakespearean sonnets!

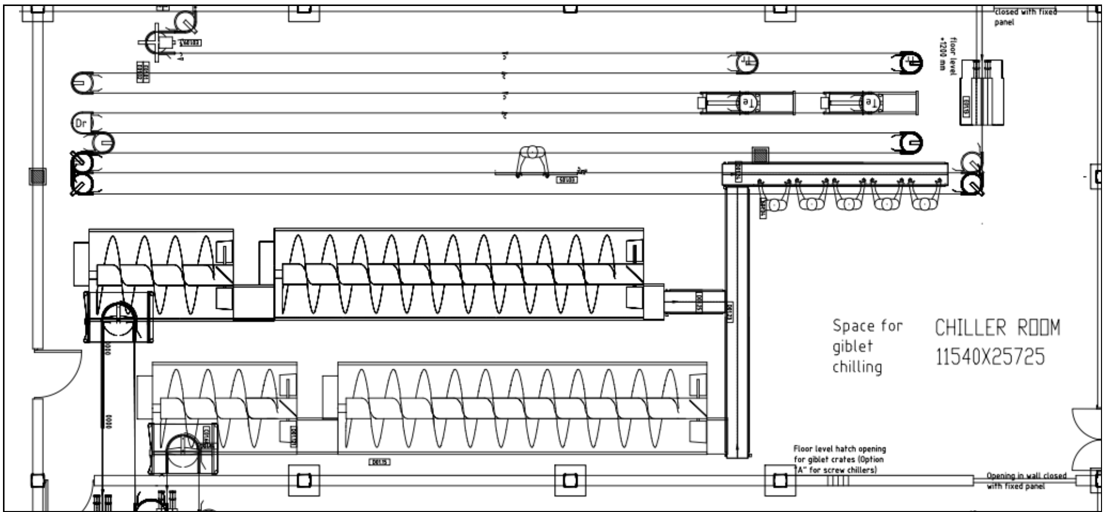


Figure 23 Here is Aptec's solution to the above incorrect layout of the screw chiller hall. Note that it now includes dripping space which had incorrectly been placed in the Extrudable Block (and would consequently have contributed to severe saturation of its interior). This layout also reserves space 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 which can be seen in 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 removed temporarily and the machines dragged in. Note there is a similar large door at the right hand top – to allow dragging in of any large piece of machinery all the way into the portioning hall, all the way from the live bird hanging area.

In this example Aptec solved the problem by redesigning the building using the odd grid spacing (the column footings had already been cast by the time Aptec was invited to solve the problem). We adapted and redrew the entire building to match the already-built 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 Example 2 In figure 24 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 shaded doors A and B shown in this drawing.

These simple modifications provide sufficient space for all ten large machines to be moved in or out or be replaced when needed. By making these changes the overhead conveyor track length increased by a mere 2420 mm (or the equivalent of 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. Providing two doors located at opposite ends in a workplace that houses several workers is a mandatory safety requirement.

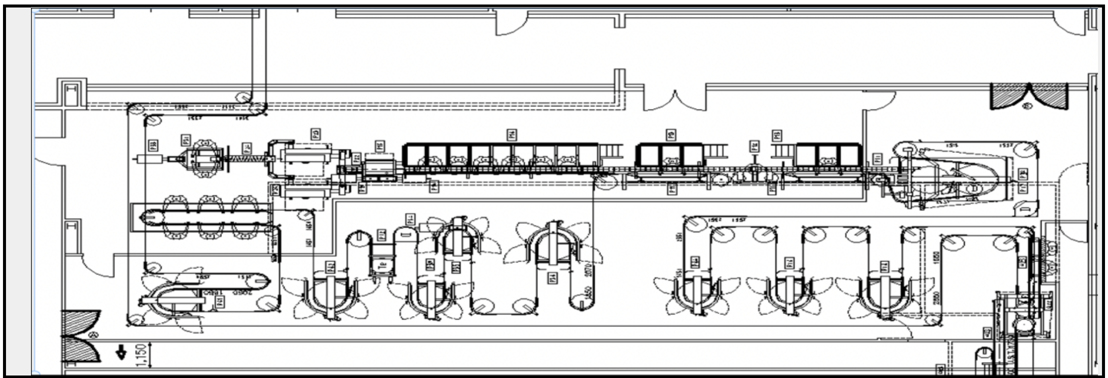


Figure 24 This drawing shows the evisceration department of a 12000 BPH plant set up somewhere in the UK. The 29.7x10.8m (321 SqM) hall houses 13 large machines (not counting the platforms for manual work), each of which was either brought into the space first and later enclosed within the sandwich panel walls – **"sarcophagus-style".**

For a moment consider a 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. They would need to navigate a complicated path around the machines in order to flee. Then further imagine what additional complications would ensue if the lights went out simultaneously. 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.

We have conjured up the above scenario not to exaggerate the stand we have taken or advise you to take. If you believe all of this amounts to scare-mongering, read Chapter 5 on materials and safety. It analyses in the form of a case study, a poultry slaughterhouse fire at Jilin in China in mid 2013 in which 121 people lost their lives. Ask yourself: are you a responsible designer or an undertaker's assistant?

Figure 25 Over-ground petroleum pipes laid over terrain prone to freezing in winter.

4.6 Does Your Design Cater For Frost Heave?

The earliest practical and economically significant instances of frost heave occurred when pipelines for the transport of petroleum fuels through permafrost and freeze-prone terrain were laid. 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.

What caused this? Small amounts of water in the soil under the masonry supports freeze in the cold and since ice has a lower density than water (it expands by 9% upon freezing[11] which is why ice cubes float in your glass of drink), the soil beneath the supports expanded. Since the soil under the support had already been compacted for stability, the soil did not absorb the expansion ant it forced the foundation upwards and caused misalignment of the pipeline. 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 are laid.

4.6.1 Frost Heave in Slaughterhouses

What does frost heave have to do with the 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 the 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 temperature 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 restricts the exchange of liquid water between the ground and the frozen store.

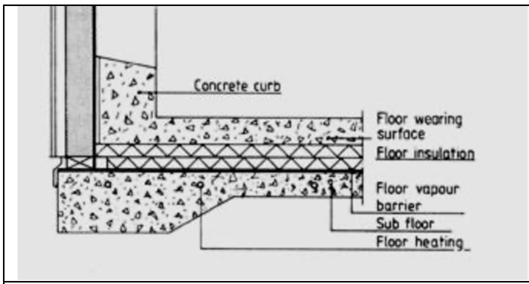


Figure 26 Construction of the buried sub-floor structure of your sub-zero floors[12]

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 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. In other words a positive feedback occurs.

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:

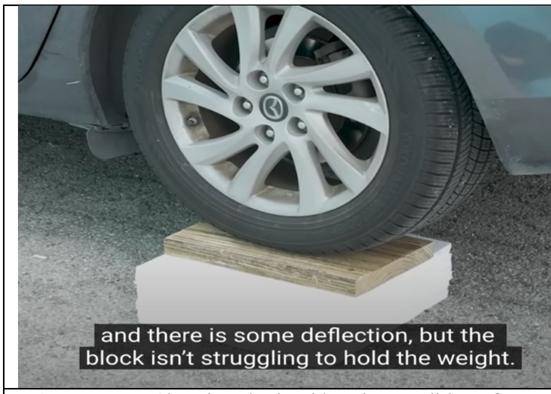


Figure 27 Showing the load bearing qualities of polystyrene foam block. This is the property, combined with its thermal barrier properties which makes it suitable for floor insulation. Even so, it can get compressed through the persistent action of frost heave.

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

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 80 Centigrade degrees across an aggregate structure 150-200mm thick would soon become the cause of a catastrophic failure! But 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 large diameter pipeline 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 be extended beyond the plinth. But there are complications to such a design. We discuss these complications here.

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 **contiguity as well as compactness in the sub-zero area.**

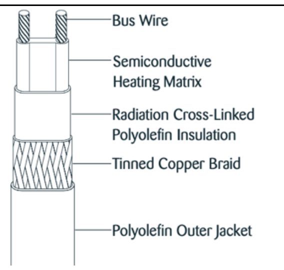
Secondly such pipes must be laid with care so that they slope down towards one of the plinth walls in order to get rid of any condensation that is sure to occur within.

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 an extractor fan. Now the speed of the fans can be modulated by the amplified signal from 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 (the ambience in this room is always somewhat warm), 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 28 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°C
Maximum operating temperature at power-on +65°C
Max exposure temperature at power-off +85°C
Circuit protection - 30mA external ground fault protection required
Bus wire – 18 AWG nickel coated copper
Metallic braid - 12 AWG copper

Figure 28 Features of a self-regulating anti-frost-heave element[13].

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 wiring 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. But remember that the finished floor level in the entire plant must be the same. A slaughterhouse should not have different floor levels. Therefore these details must be finalised well before work on constructing the floor commences.

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. This being the case, every time someone exits the process building and returns to it, he will have walked on the internal roads and picked up some dried bird droppings and feathers on his shoes and fine dust containing dried bird droppings on his person and clothing and bring it back into the process building. Foot baths help, but only to an extent. 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. If a laboratory building is not housed inside the process area you will effectively compromise the biosecurity of your plant.

Ideally from the time workers and laboratory staff check in, to the time they leave for the day, they should be retained within the process building. To this end in a well designed plant 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 itself by aerosols in the ambient air inside the process area is adequately met by an engineered ventilation system within the plant as explained in Chapter 4.

Unfortunately recent rules enunciated by Indian authorities specify that the plant laboratory be located outside the main process building. With such a rule having been specified, murphy's law will operate with a vengeance and this provision will cause more biosecurity issues than it hopes to control. In our opinion while this rule hopes to curtail the practice of locating makeshift "laboratories" within plant buildings, (an objective we applaud), it ought to recognise the futility of imposing this condition universally. To do so would be to ignore the relevance of a purpose-designed and constructed engineered ventilation system for a campus that simply cannot be made rid of bird feathers and droppings on its internal roads.

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 with 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 overhead track dimensions and then estimate the price bid. He may even be willing to offer some advice if you insist, but he will always take pains to pronounce that he is not bound by it and that you should cross-check with experts.

If you have read Chapters 2, 4 and 5, 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, principles of industrial designing and local construction skills. At present there are three main vendors of poultry processing plants worldwide and from long experience we know that neither their representatives, nor even their draftsmen are proficient in all these fields. Some of their senior project management 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 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 or deserve. 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 such vendors 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. That 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 several innovative and out-of-the-box modifications including 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 cautioning his customer against precipitate and amateur action. 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 till date[14].

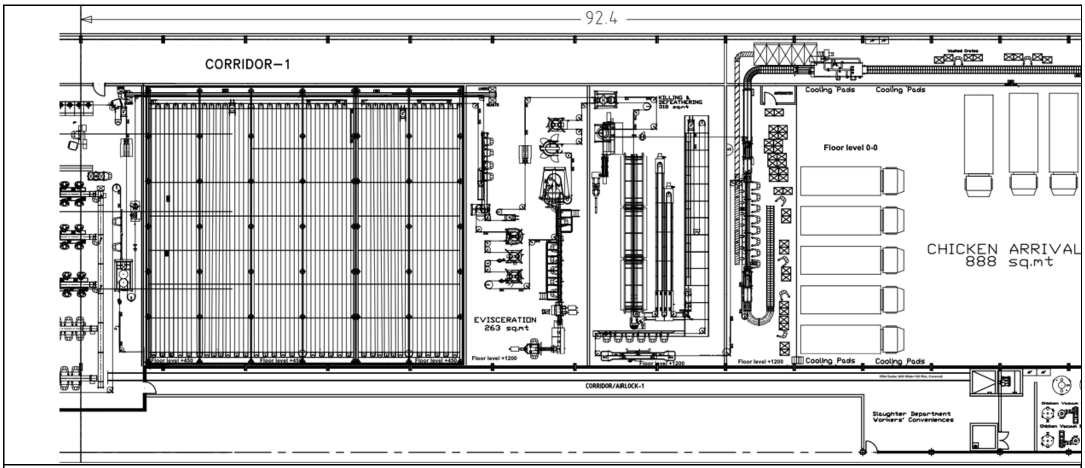


Figure 29 Showing plan of an all panel building meant to house an 8000 BPH poultry slaughterhouse to be constructed in Western India. The offal pit and associated machines are in part of the main shed, of which other details are omitted here for clarity. Note that this plant is designed for air chilling.

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 finally 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.

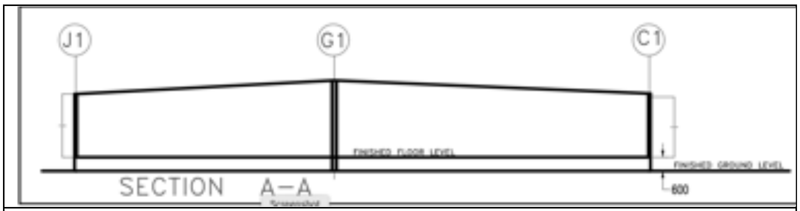


Figure 30 Elevation of the building shown in figure 29. The span width is 36.5m, with an off-central row of steel columns.

What happens when a customer makes changes in his layout and returns to the original vendor for an upgrade or expansion after a few years? Without fail the Vendor’s HO maintains no record of such changes, possibly beyond a year or two, not even of changes approved by themselves. The HO maintains only a copy of the initial concept drawing, but not a shred of information of the building or layout “as constructed” or as “subsequently modified”. It has been Aptec’s experience that feedback by way of information meant to correct official records at HO are routinely ignored by the vendor. This is because no one at the vendor HO is tasked with this responsibility.

This attitude not only causes subsequent engineering problems but more importantly has safety implications. Chapter 5 describes how during a devastating fire in China in 2013, the only information available fire-rescue came from two antiquated "concept drawings". They bore no resemblance to the "as modified" status. This frustrated rescue operations and eventually led to the death of 121 workers.

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 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 an expansion order is in their hands.

4.9 Drawing Conventions

As a project manager you will have to deal with drawings all the time, so it is important for you to be familiar with the convention.

Chronology At the beginning you will receive **concept drawings**. These are not meant for construction – they are simply options for you to visualize the arrangement of production elements, their positions, spacing and sequence. After deliberations, you will seek drawings meant for actual construction. These will come from the **architect**, following his consultations with **structural engineers** and technologists – these typically being the **vendor** and the **consultant**.

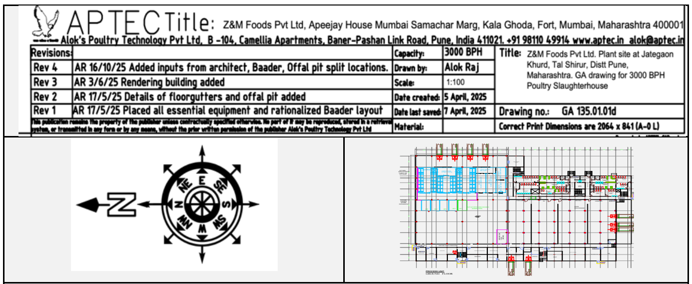


Figure 31 The top figure shows a typical **boilerplate** with clear **identifiers**. To facilitate understanding of the sequence of events leading to the composition of that drawing drawn from the company's archive, a diary of action sequence is included in the boilerplate as shown. At bottom left is a compass symbol which is essential to prevent orientation mistakes. Some **architects** insist on adopting the ancient convention of keeping north as orthogonal top of the page. This is a bad practice and makes it difficult to **orient** constructed elements and features **orthogonally**. On the right is a typical architect's layout **iteration** completely lacking **identifiers**. You must refuse to accept such sloppy drawings.

Construction drawings may be issued through one or more **iterations**, each of which should carry a **boilerplate identifier** which names the agency issuing it, the date and drawing version number. Figure 31 shows a typical iteration issued by an architect, which fails to show identifiers. You must refuse to accept drawing unless identifiers are clearly in place. Lacking clear identifiers such drawings are just scraps of paper, signifying that the issuing agency's laziness, lack of professionalism and his reluctance to take responsibility for the document or any work carried out at the site on the basis of his submission.

Construction begins when the construction team receives the final drawing bearing the legend "**issued for construction**" or "**fit for construction**". Conversely, those drawings which are not to be constructed as shown must carry the legend "**not fit for construction**" or "**not issued for construction**" or "**concept drawing**". In the course of construction several **versions** of the fit for construction drawing may be issued. It is important for the construction team to enquire if the version in his hands is current, say, version 'd' bearing the date 12/03/25 is the latest. It is the responsibility of the project manager to ensure that the construction team has at hand and is making use of the latest version. Make sure to avoid confusion between the dd/mm/yy and mm/dd/yy conventions. When in doubt, use the expanded form dd/mmm/yy.

'As Constructed' Drawing When construction ends it will have been done with reference to several versions of the **fit for construction** drawing. It is the responsibility of the project manager to ask the agencies to collate all the versions and issue an "**as constructed**" version of the drawing. This drawing must be composite, detailing **ALL** systems, and include the final outcome of **ALL** iterations. When such a drawing is at hand, the project manager must get copies printed, framed and displayed at all strategic positions in the plant building and outside it, to serve as **an aid for disaster management**. Failure to do so may result in the human tragedy described in Chapter 5. Furthermore, addenda or revisions of this drawing may be called on whenever there are substantial modifications, deletions, additions or other changes made, with the condition that these must likewise be on display. This is called the "**as modified**" version of the drawing. A copy of this drawing must be given to the principal vendor(s) when you seek their further involvement.

Supervision With smartphones it is possible to have and use utilities that can display the salient features of a CAD drawing. This is convenient, but can cause major mistakes. Take for instance when Aptec issued a version clearly earmarking a particular column to remain 'on-hold-till-further-clarifications' was received by the project manager in one instance, he made use of a partial view of the drawing and failed to notice this instruction. That column was built and had eventually to be dismantled. The project team is welcome to the convenience of a smartphone, but it must also have access to a computer. If the team does not have a CAD program, it can download a free utility that allows it to access *.DWG files, complete with layers and dimensioning tools.

5 Examples Of Advanced Process Building Layouts

5.1 All Sandwich Panel Buildings

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 29 shows the plan and figure 30 the elevation. It incorporates an air-chill system, the first ever proposed for India. Fortunately this plant was never constructed because the choice of an air-chill system was again taken up for a later, smaller plant. It failed to interest Indian customers of processed poultry. You can read about it and the futile attempts made the management to modify the air-chill system to spray-chill system in Chapter 11. Refer Section 3.2 and table 17 to learn about the salient difference between an RCC slab roof - brick wall building and sandwich panel building and our recommendations on the subject.

5.2 Hybrid Buildings

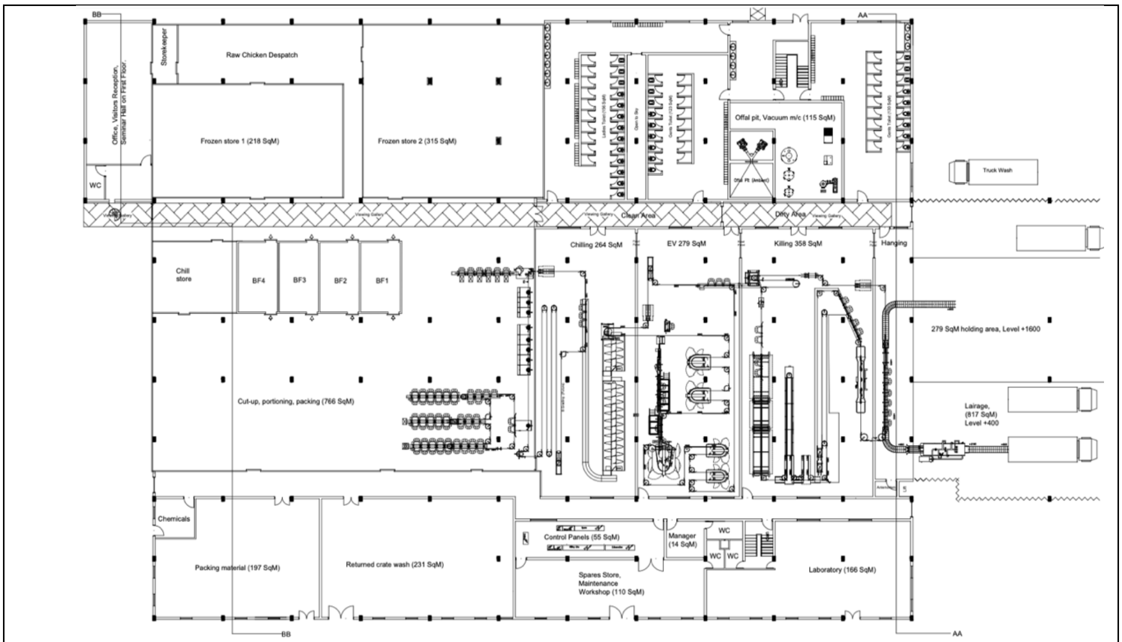


Figure 31 A 4000/8000 BPH poultry slaughterhouse layout design for Sri Lanka. This design incorporates both Inflexible and Extrudable Blocks but the former is additionally covered by an extension of the sheet steel roof to suit heavy rainfall in Sri Lanka. Because of this a lot of unused space became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

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 (figure 39) caters to a combined raw chicken and RTE products facility.

5.2.1 Hybrid Building With Sheet Roof

During a discussion 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 therefore set about arranging several service areas within that space.

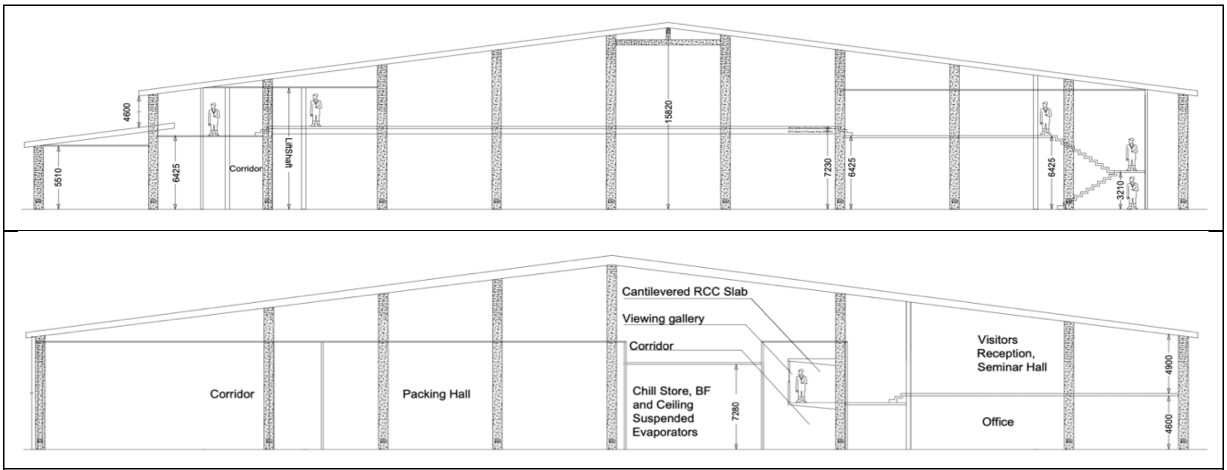


Figure 32 Cross sections of the building shown in figure 31. At the top is a section through the Inflexible Block at AA-AA, showing various service areas, making use of the space between the RCC roof and the sheet steel roof. At the bottom is a cross section through the Extrudable Block at BB-BB. Note how the viewing gallery is cantilevered from columns.

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 32. 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.

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 (see the plan view). The existing left wall of the building would then move one block distance and align with the left wall of the office annexe. 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.

5.2.2 Standard Hybrid Building

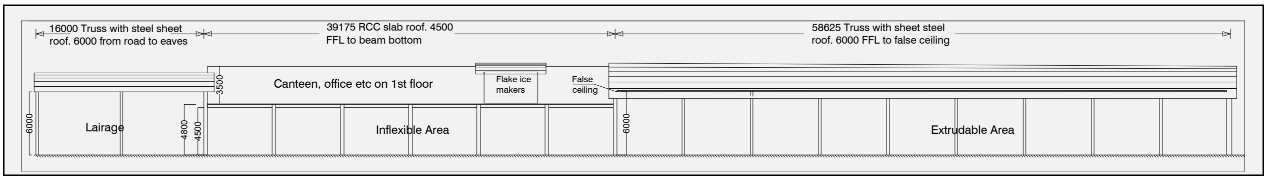


Figure 33 Elevation of the plan shown in figure 34. This layout is for a starting capacity of 2500 BPH and a peak final capacity of 6000 BPH. Note the dimensions and heights.

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

In figure 34 the canteen and office area lies over the workers' rest rooms 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 (next to the viewing gallery) – normally blocked with sandwich panels but always opened and made temporarily available for taking in new machines during expansion.

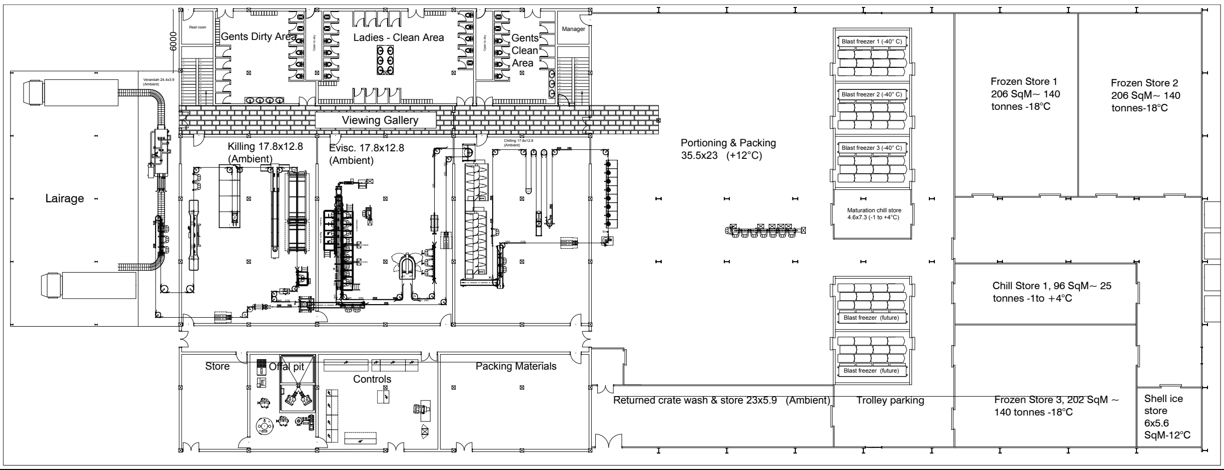


Figure 34 A 2500/6000 BPH processing building drawing showing the starting configuration. When you compare this layout drawing with the one shown in figure 35 you will appreciate that since the equipment placement was done right at the outset, expansion can occur with a very small downtime.

At 6000 BPH the layout takes on the form shown in figure 35. Note that none of the already installed 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.

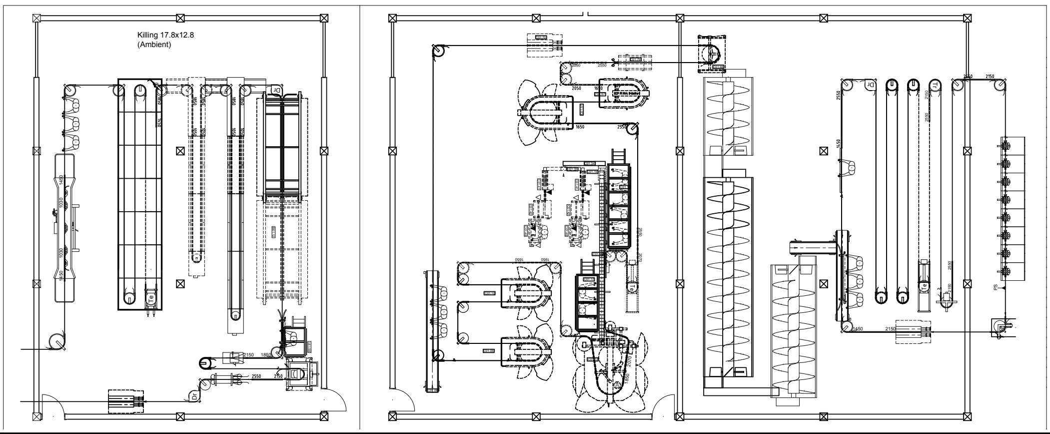


Figure 35 Except for the arrival and live bird hanging department all three halls within the Inflexible Block of the layout of figure 34 are shown here at a higher magnification for clarity.

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. 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 by the German firm.

Some years later, this 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 RTE section of the plant. The problem was so severe that it impacted product quality adversely[15] 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 for him.

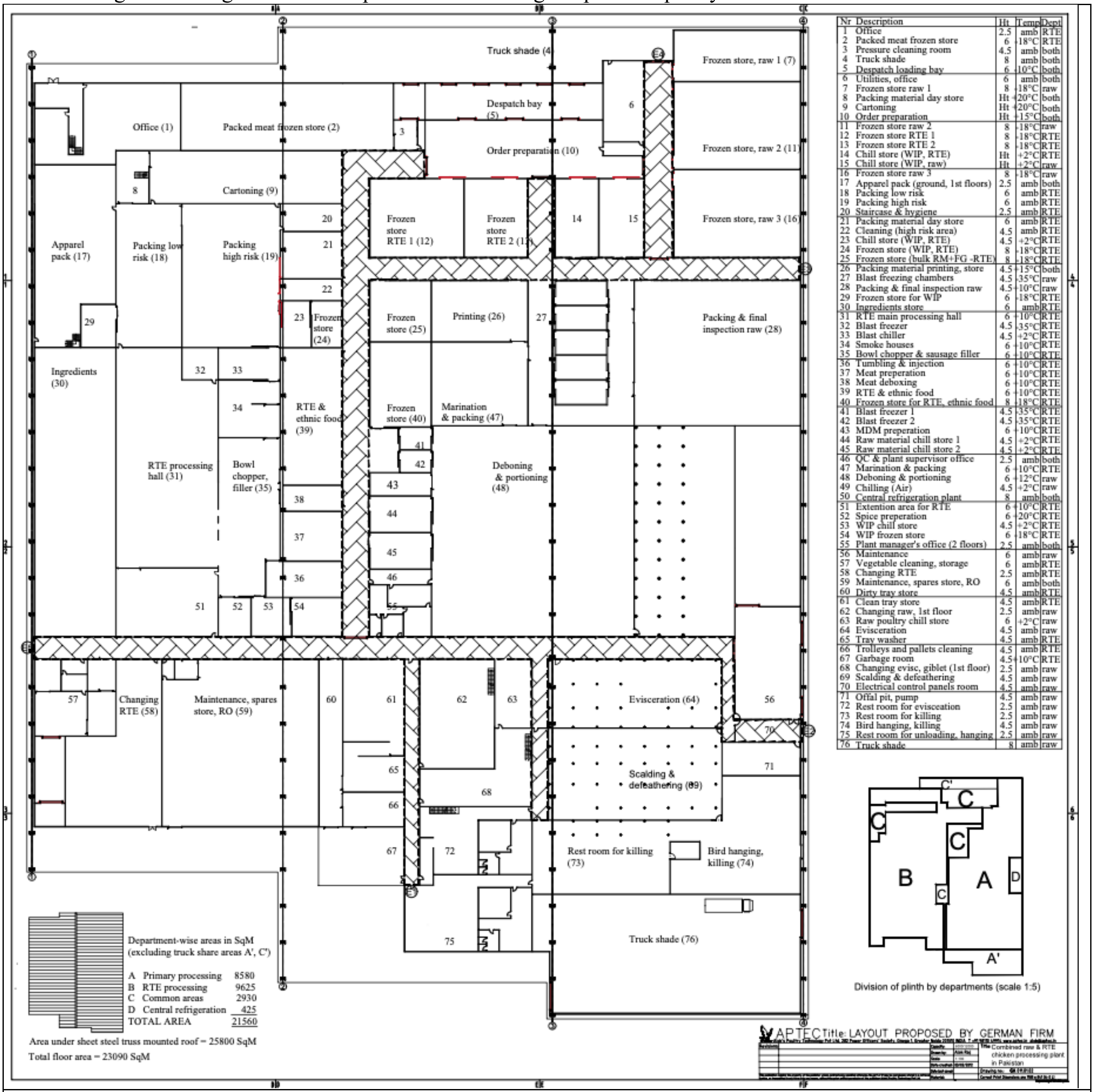


Figure 37 Showing the layout of a combined raw poultry meat and RTE products to operate at 6000 BPH initially and capable of expansion to 12000 BPH. The layout was finally arrived at after several iterations by a firm of German butchers for a client in Pakistan around 2013.

Aptec submitted an answer which forms the subject matter of Chapter 4 on the need for an engineered ventilation system within the plant for biosecurity & efficiency. When you look at figure 39, which is an expanded version of the RTE space shown in figure 38 as Aptec's initial design, you will note that it contains far fewer chambers than the RTE sections of figure 36 do. This was one of the main reasons for the high humidity and condensation problem faced by the customer. When air-space within a building is sub-divided into a multitude of hermetically sealed chambers, and these chambers have different internal heights, it becomes difficult to engineer ventilation. Ambient air tends to stand still in each chamber and get saturated. Then moisture from that stale and saturated air condenses on the ceiling, becomes a repository for aerosol contaminants and eventually rains down on the product and contaminates it in turn.

A firm of butchers familiar with ambient conditions in colder Germany where the humidity levels are far lower would not know of these special conditions prevailing in tropical Pakistan. So their design suffered from this shortcoming. Unfortunately, the RTE sections and raw chicken sections were so intimately dispersed throughout the building, it was not possible to correct this shortcoming.

This design of figure 37 makes a useful case study and a means to review the rules enunciated in this Chapter. Later, after an appraisal of this faulty design, we present the rejected alternative design submitted by us here as figure 39 in Section 5.3.2. As he examines each aspect of the designs, the reader will find it useful to switch between figures 37 and 39 and refer to the points listed in section 5.3.1 and table 38 to understand Aptec's solutions to such problems, (which we had anticipated and catered for when we had made our unsuccessful bid) in the very beginning.

5.3.1 An Appraisal of The Raw + RTE Plant Layout

(a) Mixing Raw & RTE Meat Under One 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 that handle them. This may best be achieved by adopting separation of these products at the layout stage itself.[16] The design in figure 37 fails entirely in this respect. The cross-contamination prevention guidelines were issued by the University of South Carolina Meat-Poultry Inspection Department back in 1999 - long before the layout 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[17]. There are also hazards presented by ingress of several other bacterial species in such situations. We cover them in Chapters 7 and 8.

FSIS later published a checklist in 2018 on conditions prevailing in plants producing raw meat[18]. For live bird receipt, hanging, stunning and bleeding areas they specify design & 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 Chapter 4 relating to engineered ventilation of the poultry slaughterhouse for biosecurity & efficiency.

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 in the layout of figure 37 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 in this design.

(b) Covered Area Figure 37 has a plinth area of 2.30 hectares (5.9 acres) under a single roof. The Chinese plant of Jilin Baoyuanfeng[19] 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 human lives. You can read about this Chinese plant fire in Chapter 5 where it has been presented as a case study

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. 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 Chapter 5. You can also compare this with the reconstructed layout of the Jilin Baoyuanfeng plant presented in that Chapter and mull over the implications.

(c) **Construction Material** All partition and external walls and roof proposed in figure 37 are made of sandwich panels of various thicknesses depending on the desired working temperatures within. In Chapter 5 and in section 3.2.2 of this Chapter, this matter has been covered in detail and recommended against, in the interests of safety.

(d) **The Square Design Obsession** Architects familiar with work in cold climates are very fond of extolling the virtues of the square building design because they perceive this design to be efficient in conserving heat, in exactly the same way that such buildings are efficient in keeping cool by air conditioning, in warm climates. Yet such a design makes ventilation and natural lighting that much more difficult and expensive. In fact so prevalent is this design obsession that we choose to cover it separately in section 6, where we use one of the earliest versions of the German firm's design where the squareness theme is more evident, as an example of a square design and discuss its various aspects[20]. Additionally, that the square design adversely affects ventilation and consequently biosecurity, is discussed in various sections of Chapter 4.

(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 accentuated here 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 or for widening of product mix. 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 but such a decision was foreclosed because of the choice of sandwich panel roof.

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 because customers viewed the dry appearance of air chilled carcasses as a negative product attribute. As in this case, that customer had likewise opted for a final, inflexible layout and had no space to switch back 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 as many as 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 37, you will encounter 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. All these complications worsen the prospects of an emergency evacuation in the event of a fire.

(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 going up and going down any pair of staircases, design of the first floor would be even more complicated than the ground floor. We do not have further details on this.

(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 summed up a comparison of the features of this design, contrasted them with the USDA directives and derived simple rules for designing combined product layouts in table 38.

Table 38 **Does the General Arrangement Layout In Figure 37 Conform With USDA Regulations?**

	USDA Regulations	Compliance?
1	Exposed cooked product areas should be physically separated from other areas of the establishment. Non-pedestrian passage openings (hatch 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 from passing through. Alternatively transfer may occur through corridors or passages that are not used for general pedestrian traffic. An examination of figure 37 shows that this rule has been flouted in scores of locations within the layout. On the other hand, in figure 39, 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 is made to move through 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 the 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 whether such a planned ventilation system, even if it was designed and implemented, would or would not have worked here. Note the complex intermeshing of raw and RTE processing areas in the inset of figure 37. 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.
3	Environmental control equipment such as fans and evaporator condensation pans should not be located above the product.	The general arrangement shown in figure 37 does not indicate these things one way or another.
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 for use with exposed cooked product.	The general arrangement drawing of figure 37 already specifies separate freezing & chilling chambers.

5.3.2 Raw & RTE Poultry Products – An Alternative Layout

Figure 39 shows how Aptec's layout for a combined raw cum RTE plant differs from the one shown in figure 37. 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 39. 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 an emergency. Note also that a fire tender can access the central refrigeration plant from any direction. This is an additional safety feature.

How does one deliver raw meat to the RTE section? At the raw meat end of the corridor is a crate cum trolley wash (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 1 opens and you move into the corridor with your trolley-load of raw meat. As you do so, door 2 remains shut till you reach it. Then door 2 opens and lets you in even as door 1 shuts automatically and remains shut till you reach it on the return journey.

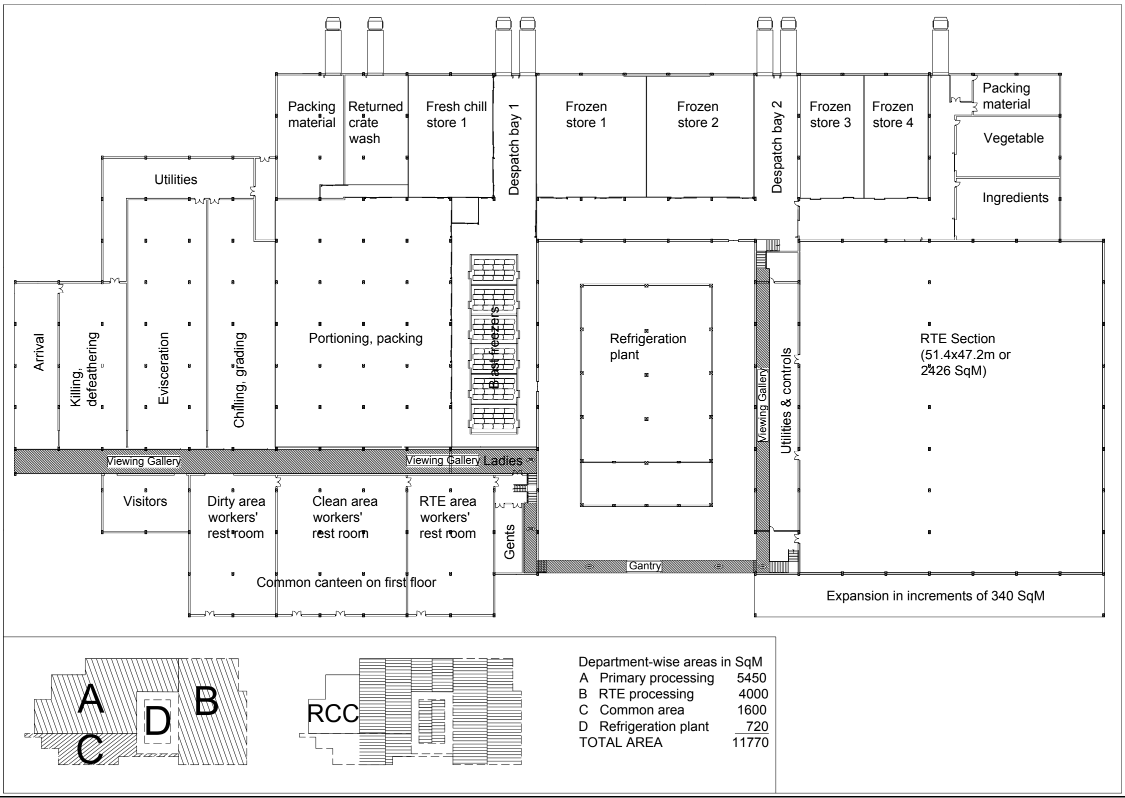


Figure 39 Aptec's alternative layout drawing (shown here with minor modifications from the original), was initially presented to the Pakistani client and got rejected. However the same layout drawing was presented two years later for an Indian project. From this layout you can easily understand how all the errors could have easily been corrected.

In this way trolley loads of raw meat are manually delivered to door 2 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 reefers to send different product shipments to institutional customers without having to duplicate transportation.

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 (and fire tenders) to the central refrigeration plant.

In the layout shown in figure 37 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 their extraordinary high area allocation for RTE in layout 39, 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, Aptec offered the basic design, to which an experienced Iranian-British expert on RTE facilities later added an area measuring 50x40 metres for the RTE section. This layout appears in figure 39. 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 9625 SqM for RTE in figure 37 was several times in excess of requirements. Note also that figure 38 requires far fewer internal partitions – a condition which would have prevented trapped moisture in the ambience and the constant nuisance and contamination from condensation dropping on the products in process.

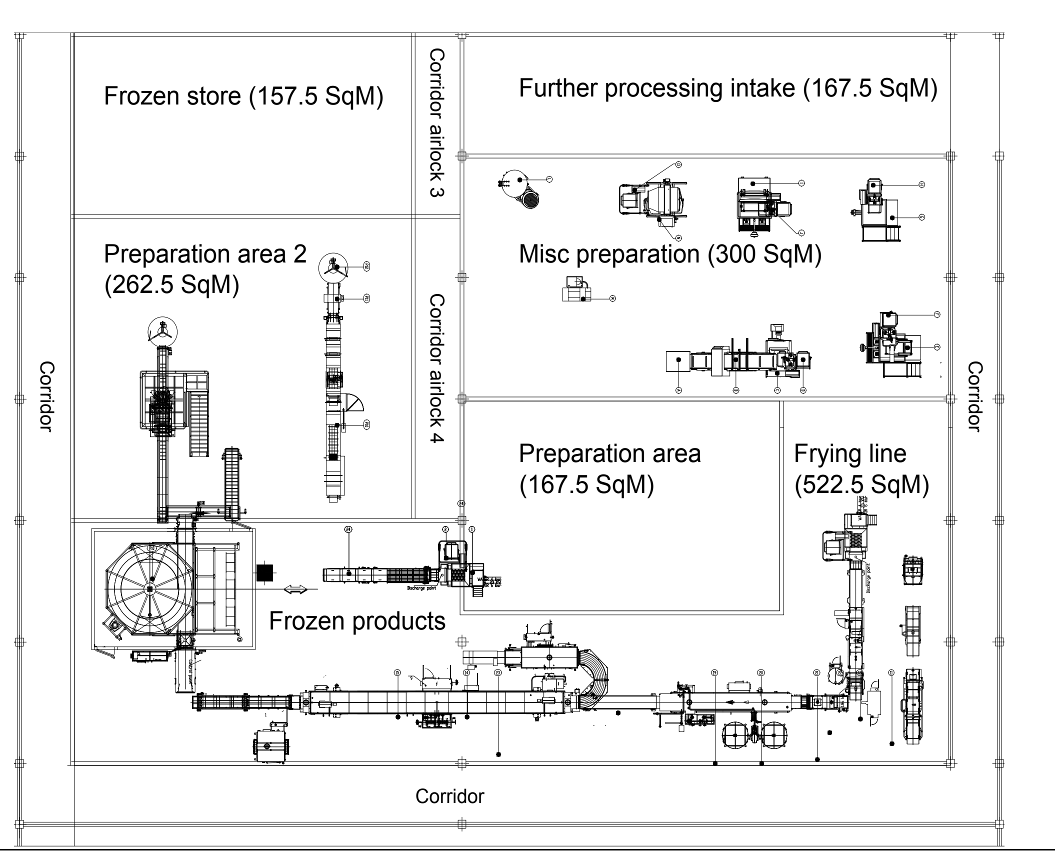


Figure 40 Layout drawing of a suitable RTE plant drawn by an Iranian-British expert for an RTE products project. It measures 50x40m and can easily fit into the layout drawing of figure 39 in the 2426 SqM space reserved for the RTE department.

6 The Square Building Mindset

Factory buildings and many public spaces such as shopping plazas and malls are now increasingly designed around steel frame, corrugated steel roofs on trusses, prefabricated concrete exterior wall panels, 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 approach.

But 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 frittered away – 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 37 has clearly not done so, simply to reduce pipeline lengths.

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

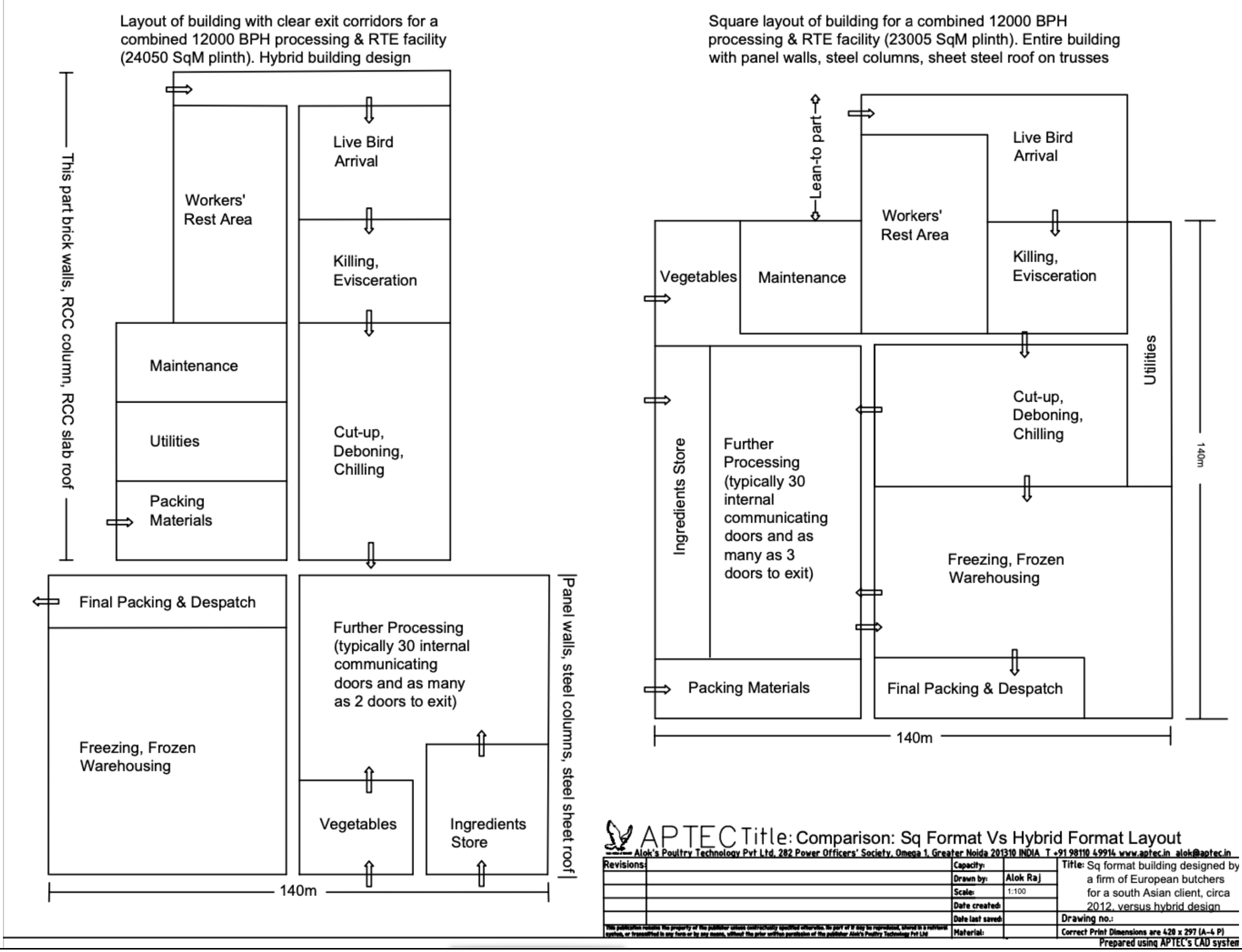


Figure 41 A comparison of physical properties of alternative building shapes proposed for a raw chicken cum RTE facility. For comparison we have retained the design floor area of 21560 SqM of the original square design of figure 37, although we have shown that this is an excessively large area and that the total area of figure 39 would have been sufficient.

Additionally, in the food processing industry buildings that make extensive use of ammonia as refrigerant as well as make use of large quantities of sandwich panels, the structure resembles *buildings within buildings* as it were. In such cases not only do distances to exits increase, but a greater potential exists 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 till it fits into available spaces. Recall that the layout principle in slaughterhouse design follows certain cardinal rules – department locations 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 Chapter 5.

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 serving different functions. Imagine the complex exit routes when you consider that the straight distance into the Jilin Baoyuanfeng 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, note how much worse the situation would be for this 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 our context, 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 41. The square design is based on an early iteration of the design that resulted in the figure 37 variant. Now compare it with Aptec's design presented on the left in figure 41.

If we assume that both versions have an average height of 8.5 metres, then the external surface area of the Aptec 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 exits, a 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 Chapter, 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.

Endnotes

[1] Chapter 2 of this Handbook.

[2] SKU means Stock Keeping Unit. This equates to the number of product packs you stock, typically in an FMCG industry like poultry processing. There will be packs by product type (for example whole legs, whole legs skin-on, drumsticks bone in, drumstick skin-on and so on); by weight category (for example 250 gram pack, 400 gram pack and so on); by chilling treatment (for example fresh chilled, frozen) and so on.

[3] 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

[4] Notwithstanding the sound logic presented here, this kind of phasing of machines is not favoured by Marel who like to sell their Nuova eviscerator in phase 1 itself and get the client committed to the system, for fear that the client may migrate to the competition in phase 2 and then for technological reasons their chances of selling the Nuova becomes dim.

[5] 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.

[6] Unless you use full automation here with 6000 products or 8000 products per hour capacities. Aptec does not recommend these machines because the 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.

[7] 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 produces an equal quantity of wastewater. This wastewater 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 law 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.

[8] 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.

[9] 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.

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

[11] 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.

[12] 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

[13] 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

[14] 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-holding of value from their overseas vendors. So this 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.

[15] 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.

[16] 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

[17] 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

[18] 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

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

[20] 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.