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Chilling, Chiller Design, Choosing a Good Machine and Troubleshooting

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1 Introduction

The first practical chiller design was placed in the market by Morris and Associates of USA some 40 years ago. Figure 1 shows several views of it. The main features distinguishing this design were counter-current flow, an optimized fabrication design of screw flights, a modular structure and an integral un-loader. In time major poultry machinery manufacturers adopted this design and modified it to suit their needs.

Figure 1 Views of screw chillers produced by Morris And Associates. The picture on the right shows details of screw flights and shaft. Pictures taken from the website of the company – http://morris-associates.com

Many variations of this design are available from the principal vendors today. These variations are:

- Shell diameters varying from approximately 1200mm to 2100mm
- Screw and un-loader mechanically coupled together and driven by one motor-gearbox combination, or un-loader being provided with a separate drive so that its rotation RPM remains independent of the screw rotation RPM. The screw speed may then be kept as low as possible to get more dwell time and the un-loader speed can be higher to ensure adequate evacuation.
- Single bath configuration or multiple baths ganged together and driven by one motor-gearbox combination
- Mechanical versus frequency controller (VLC) dependent speed regulation

In the remainder of this article I will discuss these variations and their impact on chilling efficiency. But first of all a discussion on the need for chilling.

2 Chilling Poultry

When it emerges from the evisceration section, poultry carcass is at a high temperature – typically around 40 ^{o}C. This temperature is ideal for bacterial growth and multiplication and therefore the carcass must be rapidly brought down to as near 4 ^{o}C as possible because at this temperature bacterial multiplication is virtually arrested. Therefore chilling is the single most important factor in ensuring product quality and shelf-life.

Four methods are in use today for attempting this. These are:

- Placing the carcasses in a static bath containing a slush of cold water and ice.

- Screw chilling
- Air chilling
- A combination of screw and air chilling

Although entailing the lowest capital cost, the static bath solution is the least efficient. Firstly since carcasses float in water (because they have nearly the same density as water), they do not make optimum contact with the cooling medium. Secondly, this method does not afford a means of washing the carcasses. Finally this method gives variable results – amount of ice in the bath varies, sunken carcasses cool more than those on top, the cooling medium gets progressively contaminated with debris and finally there is no cross-current chilling- in fact there is no flow at all.

Some local fabricators have combined these worst features in their screw chiller designs. Here is a picture of one (figure 2). The water discharge point is directly below the cold water inlet in this one – making it a static bath. If it works like a static bath, as it does, what in heaven's name is the purpose of providing this machine with a screw and drive?

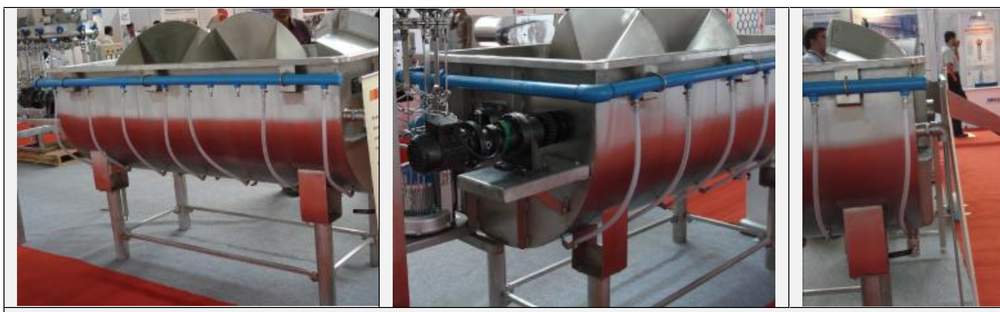

Figure 2 In this local model the screw and its drive (middle view) are completely superfluous – the machine is designed to masquerade like a screw chiller and function like a static tank. Note the picture on the right shows the carcass discharge at the top and water outlet at the bottom – exhibiting a complete departure from the counter-current principle.

When you specify your needs, target carcass temperature must be mentioned in your enquiry. So also must the average or maximum carcass size. Vendors will specify anything from 7 ^{o}C down to 4 ^{o}C target temperatures together with maximum or average carcass size in their offers. Be very clear what you order.

3 Carcass Size, Live-bird Price Volatility and Choice of Chiller Capacity

As regards carcass size, several points need to be considered. In a highly price-volatile market such as that prevailing in South Asia, the average bird size arriving at your plant will vary according to the prevailing live bird price in the marketplace. When there is a glut, farmers hold their flock longer in the hope that prices may rise tomorrow. In the meantime the bird gets fatter and fatter…

Also, when there is a glut, for a processor it is the ideal time to process more birds and place the carcasses in the frozen store. Therefore in a glut you process in excess of your capacity and you also process larger carcasses. Therefore if you had not been wise in specifying a generous size for your screw chillers at the outset, you suffer on both counts!

In any farm individual live-weights will follow the normal distribution curve – very few of the birds will be of average weight. So it is always best to specify the “*average* weight of carcass to be processed” at a higher value than the simple average. This problem becomes more acute when you aim to process birds aggregated from several farms on any given day. Figure 3 explains this phenomenon

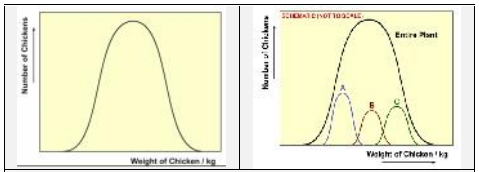

Figure 3 How the bell-shaped weight curve mandates that your chiller capacity must cater to larger birds and how aggregating live bird supplies from several farms worsens the situation

4 Carcass Size Versus Chiller Size

Chilling is governed by Newton’s Law of Cooling. Briefly it states that all other conditions being constant, the rate of chilling is longer by far for larger carcasses than smaller ones and that the rate of chilling is rapid at first (since the difference between the carcass temperature and chilling medium temperature is large) and slow as the carcass approaches the target temperature.

This is one of the reasons why international standards specify counter-current chilling. But because of their obduracy or ignorance, all local fabricators fail to follow this simple and reasonable directive.

To reach 4 °C, it requires a much longer chilling time than, say, 7 °C for any given BPH figure. For example, all other conditions being the same, it may take a one-fifteenth of your chiller length for the carcasses to fall from 35 °C to 32 °C while it may take a quarter of the chiller length to lower the same carcasses from 7 °C to 4 °C.

Chilling time and carcass size relationship for screw chilling is in the tabulation provided by Peter Kragtwijk, refrigeration expert at Meyn, excerpted here as figure 4

Time \ Gram	1.000	1.100	1.200	1.300	1.400	1.500	1.600	1.700	1.800	1.900
0	42,0	42,0	42,0	42,0	42,0	42,0	42,0	42,0	42,0	42,0
5	37,0	37,1	37,2	37,3	37,4	37,5	37,6	37,7	37,6	37,7
10	33,6	33,8	34,0	34,2	34,4	34,5	34,7	34,8	34,8	34,9
15	30,4	30,8	31,1	31,4	31,7	31,9	32,1	32,3	32,4	32,5
20	27,1	27,6	28,1	28,5	28,9	29,2	29,5	29,8	30,0	30,2
25	23,9	24,5	25,1	25,7	26,1	26,5	26,9	27,3	27,6	27,8
30	20,9	21,6	22,3	22,9	23,5	24,0	24,4	24,8	25,1	25,4
35	18,2	19,0	19,7	20,4	21,0	21,5	22,0	22,4	22,7	23,0
40	15,9	16,6	17,4	18,0	18,7	19,2	19,7	20,2	20,5	20,8
45	14,0	14,6	15,4	16,1	16,7	17,1	17,7	18,2	18,4	18,7
50	12,2	12,9	13,6	14,3	14,9	15,4	15,9	16,4	16,7	17,0
55	10,7	11,3	12,1	12,7	13,3	13,8	14,3	14,8	15,1	15,4
60	9,3	10,0	10,7	11,3	11,9	12,4	12,9	13,4	13,7	14,0
65	8,2	8,8	9,4	10,0	10,6	11,1	11,6	12,1	12,4	12,7
70	7,1	7,7	8,3	8,9	9,5	9,9	10,4	10,9	11,2	11,5
75	6,2	6,8	7,4	7,9	8,4	8,9	9,3	9,8	10,1	10,4
80	5,5	6,0	6,5	7,0	7,5	7,9	8,4	8,8	9,1	9,4
85	4,8	5,2	5,7	6,2	6,7	7,1	7,5	7,9	8,2	8,5
90	4,2	4,6	5,1	5,5	6,0	6,3	6,7	7,1	7,4	7,7
95	3,7	4,1	4,5	4,9	5,3	5,7	6,1	6,4	6,7	7,0
100	3,2	3,6	4,0	4,4	4,7	5,1	5,4	5,8	6,1	6,3
105	2,8	3,1	3,5	3,9	4,2	4,5	4,9	5,2	5,5	5,7
110	2,4	2,8	3,1	3,4	3,8	4,1	4,4	4,7	4,9	5,1
115	2,1	2,4	2,7	3,0	3,4	3,6	3,9	4,2	4,5	4,7
120	1,8	2,1	2,4	2,7	3,0	3,2	3,5	3,8	4,0	4,2
125		1,8	2,1	2,4	2,7	2,9	3,1	3,4	3,6	3,8
130			1,9	2,1	2,4	2,6	2,8	3,1	3,3	3,4
135				1,9	2,1	2,3	2,5	2,7	2,9	3,1
140					1,9	2,0	2,3	2,5	2,6	2,8
145						1,8	2,0	2,2	2,4	2,5
150							1,8	2,0	2,1	2,3
155								1,8	1,9	2,0
160										1,8

Figure 4 Time & carcass weight relationship. From Peter Kragtwijk, refrigeration expert at Meyn. Time is in minutes, carcass weight (top row) is in grams after evisceration and carcass temperatures are in the body of the table in degrees C. Initial carcass temperature is taken at +42 °C . It is assumed that the chilling medium is at between 0 °C and +2 °C.

5 Ice in the Screw Chiller

Newton's Law also indirectly makes it important for you to add flake ice to your screw chiller. It specifies that chilling rate is inversely proportional to temperature difference between the carcass and surrounding medium. How does this matter?

Consider a counter-current screw chiller. As a carcass moves to the end, its temperature falls, while the temperature of water surrounding it rises. At close to the target temperature the carcass may be at, say, 6 ^{o}C, while the water, which was introduced at 2 ^{o}C, may have risen to 4 ^{o}C. Now the temperature difference of 2 Centigrade degrees between the carcass and medium is very small and the chilling rate will be extremely slow.

To ensure that the medium remains at close to zero degrees, we need to add flake ice to it. As the ice melts, it draws heat energy from the medium, thus cooling it. Typically you need to add a quarter kg of ice for a kg of carcass to ensure this. Ice addition is best made close to the discharge end, approximately at 70% mark of the screw chiller's length measured from the carcass inlet end, on the carcass side (not the water side!) of the shaft. Flake ice is preferred to shell or tube ice or crushed ice because flake ice melts more rapidly than all other forms.

6 Water Chilling Versus Air Chilling

International standards require 2.5 litres of wash/chill water per kilogram[1] of carcass being chilled. The air-chill versus water-chill debate is essentially on five points:

- By air chilling you can save this quantity of water.
- Water chilling allows water pickup while air chilling causes desiccation – these together result in yield loss in air chilling.

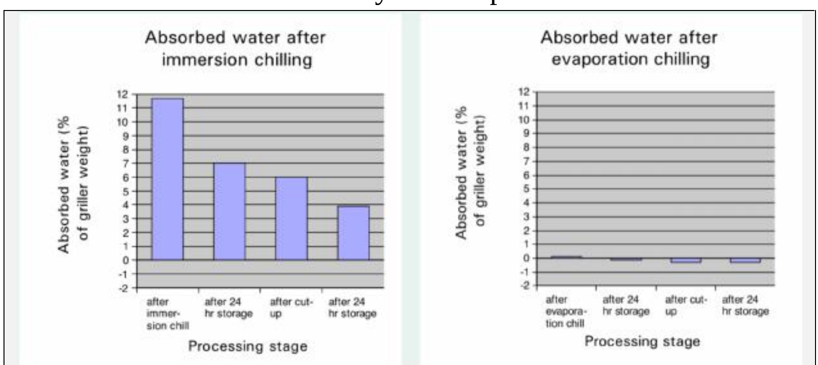

Figure 5 Research by Young and Berrang, Russel Recearch Centre, Athens GA. Poultry Science 83:119-122 (2004), brought to my notice by Peter Kragtwijk, refrigeration expert at Meyn

- Air chilling permits traceability while water chilling hinders it.
- There is a big difference in capital cost and operating cost between these processes
- Water chilling causes cross-contamination and consequently reduced shelf-life

To reduce yield loss through desiccation, most air-chill systems spray the carcass with a small quantity of water as it enters the chill tunnel. On contact with chill air this layer of moisture freezes into ice and prevents further loss of water. In the spray system a substantial quantity of sprayed water gets wasted and therefore the effective quantity of water usage may approach half of one litre per kilogram of carcass. Therefore the net water saving is only 2 litres per kilogram of carcass that is air-chilled, versus the same being water-chilled.

In a typical screw chiller a carcass picks up water amounting to approximately 3-4% of its weight. Part of this water (by some estimates half of it) goes to restore the same lost in rigor mortis – thus restoring the tone of meat. International standards permit retention of this quantity (4%) of water pick up.

On the other hand, some tissue water is lost in the air-chilling process. This may be as much as 0.5%, even when you install a spraying system as discussed above.

Therefore there is a yield difference of between 3.5% and 4% in favour of screw chilling. This point has been discussed in results of an empirical study done by Young and Berrang (figure 5). Weighted against this of course, is the difference in shelf-life.

Traceability down to specific cut or carcass requires that carcasses remain on the overhead conveyor line from the time they are hung as live birds to the time the edible product gets packaged and bar-coded to eventually reach the consumer.

Since the carcasses are dropped into a screw chiller before they are again hung onto an overhead conveyor, traceability down to the cut or carcass level is not possible with water-chilling. One can only narrow down to flock level provided the process plant allows some gap between batches entering and exiting the screw chiller. Even this is difficult to put into practice. Therefore should traceability become mandated

Comparison of Operating Cost - Airchill Versus Waterchill

Prepared by Alok Raj with inputs from Peter Kragtwijk, Meyn Holland

March 20, 2014

INPUT DESIGN DATA		**Airchill**	**Waterchill**
Capacity	BPH	2000	
Production shift	Hours	8	
Number of days of operation per year	Nos	300	
Maintenance cost as % of capital cost	%	2	
Maximum eviscerated weight	Kilograms	1.65	
Product temperature out	Deg C	4	
Conversion rate from Euro into INR	INR	85	
Depreciation rate for capital investment	%	10	
INPUT UNIT COST DATA IN INR			
Raw water (Kilolitre cost in INR)	Kilolitre	50	
Power (kWh cost in INR)	kWh	8	
Labour (1 person per day in INR)	per day	440	
Building space cost/ per SqM	INR	10000	
Derived building space cost per CuM	INR	2326	
INPUT CAPITAL COST IN INR MILLIONS			
Total delivered and installed cost comprising overhead conveyor; rehanging belt; screw chillers 1x2.1x3m +1x2.1x6m; customs duty; steel superstructure; refrigeration water coolers; ammonia coolers; pipework; Water recirculation pumps, piping; flake ice makers; building	INR Million	51.91	16.51
CALCULATED DESIGN DATA			
Water consumption	lit/hr	1000	8000
Power consumption			
Power consumption (line drives)	kW	6.9	--
Power consumption screw and blowers		--	8.2
Power consumption (fans)	kW	72	--
Power consumption (cold air)	kW	225	--
Power consumption (cold water, flake)	kW	--	239
Total power consumption		**303.9**	**247**
Comparison of Systems			
Labour cost	Mill INR/year	**0.26**	--
Depreciation on assets	Mill INR/year	5.19	1.65
Power consumption	Mill INR/year	5.83	4.75
Maintenance cost	Mill INR/year	1.04	0.33
		12.33	**6.73**
Cost per carcass	**INR**	**2.57**	**1.40**

Figure 6 Capital cost and operating cost comparison for chilling arrangements in a 2000 BPH plant in India showing air versus water chilling options.

by law, as a technology screw chilling may become extinct unless a carcass-bar-coding-on-line technology, under development, reached marketable status.

It should be borne in mind, however, that in small plants which do not install automatic re-hanging systems (automatically transferring carcasses from the killing line to evisceration line to air chilling to weighing-grading to cut-up lines, etc), traceability is not possible anyway. By small plants I refer to those which are below 6000 BPH. Since most plants in South Asia fall in this category, the traceability debate is actually about capacity and capital cost rather than about method of chilling.

Figure 6 gives a rough capital cost and operating cost comparison between air chilling and screw chilling. Note, I have not taken into account yield differences. You can recalculate values according to current market price of your whole carcasses.

7 Cross-Contamination and Shelf Life

Many pundits claim that a screw chiller causes cross-contamination because it places many carcasses into the same bath – on the argument that one or more within a batch may be contaminated and would therefore contaminate others. This is the reason cited by them for the better shelf life of air-chilled poultry because it avoids placing carcasses together. It would make more sense if a comparison of spoilage or toxin producing surface pathogen density was singled out from the observations made by such pundits, but a claim on shelf life is incorrect. Why?

Air-chilled poultry does have a longer shelf-life than water-chilled poultry. Also all air-chilled poultry carcasses from any one batch from any one plant exhibit virtually identical shelf lives.

If one were to believe the pundits' claims, then it must follow that within any given batch there will be some good carcasses and some contaminated. Only this belief would justify the above claim since it needs at least one contaminated carcass within the batch to cross-contaminate others when that batch was dropped into a screw chiller. If the above is true, there must be a variation in shelf-life of air chilled carcasses. Since this does not observed, the cross-contamination argument is false.

Furthermore, as they are transported together, closely packed in coops and are immersed in the same scalder bath, carcasses already have adequate opportunity to cross-contaminate each other even before they get dumped together into a screw chiller. In sum, scrapping screw-chilling will not prevent cross-contamination.

What does give air-chilled poultry a longer shelf-life is the absence of free water on the surface of the carcass because air-chilling dries the surface. Occurrence of a low water residue results in low water activity, designated A_w. When the A_w is low, bacteria cannot multiply.

Because air-chilled poultry has a dry surface, when this product was first introduced in India a couple of years ago, it met with consumer resistance on the plea that it appeared to be a very old product! It is useful to note that technological improvements are not all it takes to woo the customer – you also need to consider the behavioural aspect.

8 Injecting Air in Chiller Bath

To keep the carcasses fully immersed in the medium and thus ensure best heat exchange (best chilling speed) it is necessary to inject air into the medium. For this purpose one or more air compressors are provided with the chiller. They inject compressed air all along the medium.

Some plant managers object to this practice on the plea that compression causes the air to heat up and this heat is added to the water, raising its temperature. Therefore they maintain that it is better to inject no air at all!

In fact introducing air into the bath is essential to get good chilling results. And the small amount of heat transfer from compressed air to chilling medium that this entails is well worth the price one has to pay for doing so.

Encountering one such obdurate plant manager several years ago in Pakistan, who insisted that heating of the medium by compressed air nullified all the benefits of having a screw chiller altogether, I produced the following (figure 7) back-of-the-envelope calculations and explanation:

What is the role of air blown into the chiller?

Compressed air blown into the screw chiller causes the apparent specific gravity of water to fall below 1.0. which in turn causes carcasses, whose specific gravity is also close to 1.0, to sink. Only then can they come into proper thermal contact with water and cooling can occur efficiently.

The blown air also causes mixing of water by agitation, thus equalizing the temperature of the bath. Carcasses are generally mostly in one half of the chiller and there is a tendency of cold water on the less occupied section to flow as a laminar current and escape without causing adequate cooling. Hence agitation is important.

Finally the agitation of carcasses loosens the skins so that water pick up improves. Of course this happens only when there is also a minimum given density of carcasses in the chiller.

Look at it this way. Some three decades ago the paddle type chillers were common. They were specifically designed for causing agitation. They have been completely replaced by the blower type. There has to be a reason beyond simple agitation ! Some people hold the opinion that making air to pass through water causes the water to get warm. True. this it does, but to want extent?.

1	Specific heat of water	Is the energy required to raise one gram of it by a degree C. It is 1 calorie/gram °C = 4.186 joule/gram °C (which is higher than any other common substance and which is why water cools or warms so efficiently and which is also why the earth is a habitable planet).
2	Specific heat of dry air	1 joules per gram per degree C
3	Density of air	At sea level is approximately 1/800th of that of water. The density of water is 1.0
4	What calculations come into play per hour when compressed air is blown into the chiller?	320 NM^3 of air passes over 21 cubic metres of water as per following calculations: (Pi x 2.1 x 2.1 x 6 x 2/4) - (Pi x dia x dia x h x 1/4 x 1/2 x two exchanges per hour)= 20.77 Cum of water. Mass of air would be 320/800 = 0.4 tonnes and that of water would be 21 tonnes.
4	What happens when 320 NM^3 of water passes over 21 cubic metre of water?	Both sides multiplied by specific heats give 88 for water and 0.4 for air. So the ratio of temperature gain versus temperature loss is 1/220. So simply (and admittedly only approximately) put, the temperature gain of water will be at most 1/220th of the temperature loss by air provided that in the split second that it passes through the medium, warm air loses all its excess energy to the water bath! This cannot happen. The temperature ratio is therefore a negligible quantity and cannot form the basis of any plausible argument.

Figure 7 Back-of-the-envelope calculations showing that bubbling compressed air has negligible disadvantages which are far outweighed by its advantages.

9 How to Specify an Adequate, Flexible and Appropriate Configuration

9.1 Rotation Speed and Chiller Capacity

It is possible to get the best chilling performance from your screw chiller (water temperature, flow rate, ice quantity, bird size and BPH being constant), by prolonging the duration for which carcasses remain inside the bath. This is called the dwell time. Typically good screw chiller lineups for your plant's capacity will allow you to reach 35 minutes of dwell time.

You can achieve this by reducing the rotation RPM of the screw with the help of the mechanical or electronic speed regulation which any decent machine ought to have. However there are limits to which you can reduce the rotation RPM. How do you know that the best RPM has been set?

Count the number of carcasses being discharged by the chiller for a reasonable time period, say 10 minutes. The number of carcasses by your count must be a trifle more than one sixth of the BPH at which your plant is operating. (Why more than the plant BPH? Because in a good plant every succeeding section must religiously be set at a higher BPH than its preceding section so as to avoid possible accumulation at transfer points!)

When you set a speed lower than this, you are effectively allowing the screw chiller to accumulate more and more of your production as your shift progresses. Soon, a time may be reached when the mechanical load built up by this accumulation of carcasses will cause severe and irreversible structural damage to the shell of the screw chiller! I have personally attended to and repaired a screw chiller which was thus damaged owing to the plant manager's ignorance.

Go back to section 4 and note again the relationship between bird size and dwell time in the context of larger carcasses needing more dwell time to chill.

9.2 Why Not Drop Carcasses on Both Sides of the Shaft?

Section 9.1 explains the circumstances when mechanical damage of the shell is possible when the number of carcasses under dwell exceeds the capacity of the screw chiller. In a screw chiller, under normal operation, carcasses generally stay on one side of the central drive shaft. When the number of carcasses begins to exceed the capacity on the carcass side, some of them are pushed onto the water side and thus relieve structural stress of the screw chiller. Therefore the convention of moving carcasses only on one side of the drive shaft is a safety feature.

You may distribute carcasses on both sides of the drive shaft, but remember, by doing so, you would be exceeding the discharge capacity of the fixed un-loader and compromising the built-in safety feature. On the other hand, if your screw chiller has an independent drive, and you carefully monitor the transit rate of carcasses when you set the speed of the un-loader, you may drop carcasses on both sides.

9.3 Fixed Un-loader Versus Independent Un-loader

Section 9.1 explains the advantages of having an independently driven un-loader. It does entail a higher capital cost, but has advantages.

9.4 Ganged Bath Chillers Versus Separate Chillers

In many plant capacities in excess of 1300 BPH, it is common to have two or more smaller screw chillers instead of having a single large one. With such an arrangement, you generally supply water at 12-14 ^{o}C, at the flow rate of 1.8 litres per kilogram of carcass and 2 ^{o}C water at a flow rate of 0.7 litres per kilogram of carcass in the first and second chillers respectively. Taken together, these flow rates conform with the wash-water standard of 2.5 litre per kilogram.

This method has certain advantages. Firstly since water at 12-14 ^{o}C is cheaper than water at 2 ^{o}C, this reduces operating cost. Secondly it is normal to have a smaller screw chiller in the first position and maintain the rotation RPM to achieve a dwell time at close to 10 minutes. You get adequate washing performance and a small temperature drop in the carcasses in this chiller.

Before the carcasses drop into the second chiller, the feather follicles remain open as the involuntary muscles around the follicles react in this way to the comfortable temperature. But as soon as the carcasses drop into the second chiller, with water at close to 2 ^{o}C, they snap shut, entrapping a small quantity of water which goes to make up the water pick-up percentage.

In the second chiller you maintain water flow at 2 ^{o}C and also add flake ice. Since this medium is more expensive, you maintain the dwell time for approximately 25-30 minutes and keep the water flow rate low, thus maximizing the chilling effect, preserving the water pick-up, and reducing operating cost, all at once.

From the above it should be clear that these advantages are available to you only if the two screw chillers can be set for different shaft drive RPM’s. These advantages are not available to you if both screw chillers are driven by one motor-gearbox combination.

Therefore ganged screw chillers are inferior in performance to independent screw chillers. Although they save you some capital cost, they cost more to run.

Figure 8 As your plant expands, you may run out of space unless you opt for wider chillers at the outset

9.5 Shell Diameter and Its Implications on Your Choice

For a given chiller capacity the larger the diameter, the smaller the floor space it occupies.

The capacities are related by the formula d^2/D^2 where d is the smaller diameter while D is the larger diameter. Thus a metre length of 1.6m dia chiller will have a capacity of a mere 58% (1.6x1.6/2.1x2.1 = 2.56 /4.41 = 0.58) of an equivalent length of 2.1m dia chiller.

Since chillers tend to be long, it is likely that as your plant expands, you may soon run out of space (see figure 8) and not be able to purchase and install adequate chilling capacity. So it is smart to always opt for the larger diameter chiller at the outset.

9.6 Modular Construction

All locally fabricated screw chillers have welded end-plates. This is also true for some cheap Chinese fabrications. Against this, all screw chillers made by Meyn, Marel and Linco have flange jointed end-plates. As your plant grows, you will need to expand your chillers. This is not possible if you opt for welded end-plates at the outset. You will either have to scrap the existing machines or add more machines which will cost you in the aggregate more than having opted for the flange-jointed machines in the first place.

It is therefore important to select flange jointed machines at the outset (figure 9).

When you expand your flange jointed screw chillers, you simply order additional length of shell, screw and bearing, take apart your existing machine, place the new sections and bolt together the end plate again. The old drive will generally handle the new assembly – the gearbox and shaft (if not the motor) are designed to handle many additional sections and grow progressively up to as much as 21 metres in length!

Figure 9 Flange-jointed sections and end-plates versus welded end-plates. Note also the tack-welded braces on the endplate. Tack-welding is not acceptable for machinery for the food processing industry. Furthermore if braces are added for strengthening the end-plate against buckling, they should be seam-welded or they will not work. Note yet again that the brace consists of an SS channel with both ends left open to allow debris to accumulate!

9.7 Red Water Chillers

Some irresponsible companies have installed recirculation systems for their screw chillers. In this arrangement the chilling medium is in a closed circuit – with the discharged water being passed through a refrigeration (falling film) chiller so that it is cooled back to 2 ^{o}C and reintroduced into the screw chiller. In time the water contains enough blood to justify the name given to this arrangement. What is wrong with it?

In a letter dated January 19, 2005, the USDA-Food Safety Inspection Service (FSIS) indicated that if water is to be reused in a poultry processing facility, then this reuse water must be accounted for in the plant's HACCP program. To prevent reuse of bad chill water (including chiller red-water re-chilling systems), the USDA enacted new regulations in CFR 416.2 (g) which mandates that measures are to be taken to reduce physical, microbiological and chemical levels for reuse. This can only be achieved by ultra-filtration of the recycled water to remove tissue debris and microbiological methods such as ozonation being made part of the recirculation circuit (i.e. placed within the Re-chiller circuit shown in figure 10). Sample points in the diagram are CCP's here.

Removal of microbes is an obvious recycling condition, but why does removal of tissue debris matter? In answer to this question we must note that as the concentration of tissue debris increases, more and more chlorine gets locked up and ceases to be bio-available for control of living microbes.

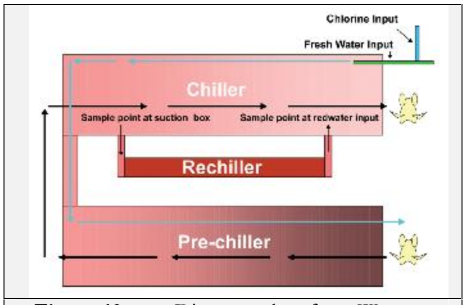

Figure 10 Diagram taken from Water Reuse in Poultry Processing – Now Addressed in the HACCP Program, Scott M. Russel, Associate Professor, Department of Poultry Science, University of Georgia

Since red water chillers perform the non-removal of tissue debris (which in this case includes blood cells), by definition, such chilling arrangements fail the physical removal condition and also lose control over the quantity of chlorine in the medium and consequently on reduction of microbes.

Much importance is placed on conservation of water in poultry processing. At the present level of technology it is not possible to recycle most of the water in an economically meaningful way in poultry processing. For a complete understanding of this subject, and for exploring ways and means of reducing consumption of water, please refer to my article "Water Recycling in Poultry Processing - State-of-The-Art Today" on www.aptec.in.

9.8 Addition of Chlorine

The best and most economical way to reduce bacteria in chicken processing involves use of chlorine in the screw chiller water. The preferred level is 15-20ppm free chlorine. Remember, when concentration of cellular debris increases, bio-availability of chlorine falls below the calculated values of any chemical assays you may conduct.

Dosatron mixing systems are the preferred method of ensuring correct dosing of a standard chlorine solution into screw chillers. However, Dosatrons are not designed to allow large water flow rates required in screw chillers. To overcome this problem, split the chilled water intake pipe into two branches before rejoining them and lead the rejoined end into the chiller. One of the split branch pipes can have a smaller diameter, consistent with Dosatron specifications and chlorine solution may be administered through this branch. The other branch may be made as large as required. Place the regulation valve upstream of the split (before the split) so that you can control flow rates in both branches simultaneously. Your valve must be followed by a flow-meter. See section 10.9 for details.

Now the ratio of pipe cross-sections between the split branches will give a rough clue to the dilution of administered chlorine occurring in the flow into the chiller. To make sure, and to make corrections for flow dynamics, carry out some tests (flake ice included), with various flow rate settings and prepare a look-up chart which your operator may consult every time he sets the chlorine flow rate on the Dosatron.

9.9 Best Configuration for South Asia

Ridding carcasses of surface bacteria is of paramount importance in poultry grown in South Asia. This can be achieved by immersing carcasses for a sufficient length of time in water containing free chlorine. Wash in the inside-outside carcass washer does not give adequate contact time. The only way to achieve this is by using screw chilling with chlorine dosing.

On the other hand, producing carcasses with a long shelf-life is equally important, especially when there is increasing demand for fresh-chilled poultry.

To my mind, therefore the best compromise is to subject carcasses to approximately 20-25 minutes of screw chilling, and follow it up with 10 minutes of air chilling. Screw chilling will reduce microbes and subsequent air chilling will give a low $A_{w.}$

10 My Chiller Has Some Problems – What Should I do?

	Symptom	Possible Reason and Remedy
1	**Chilling** is insufficient	Actual versus design BPH rates or your actual carcass size versus design parameters are not matching. You are probably processing more birds per hour than your chiller was designed for, or are processing much larger birds than your chiller was designed for, or both. In each case you need more chilling capacity.
2	**Chilling** is insufficient	Check whether: (a) You are maintaining water flow at 2.5 litres per kilogram of carcass (b) You are adding enough **flake** ice at 250 grams per kilogram of carcass (c) Your ice chute is located at approximately 30% of chiller length upstream of the discharge end (d) Your flake ice adding system has the icemaker installed on the roof slab, directly above the screw chiller or you depend on manual carting and addition of flake ice from some ice store located elsewhere. In the latter case, since you cannot monitor your workers all the time, they are probably goofing off. (e) You are bubbling air through your chiller?
3	**Chilling** is insufficient	Is your water in-feed at the specified temperature (+2 in case of single or second chiller and +12 in case of first chiller where two or more chillers are installed) Merely taking your vendor's word or measuring with a cheap Chinese probe is not enough. Thermometers can notoriously be off by as much as 10% across the scale and by 5 centigrade degrees at scale ends. You need a calibrated thermometer. Go to the nearest test laboratory and get a good thermometer calibrated and use this calibrated thermometer to calibrate all other thermometers in your plant.
4	**Chilling** is insufficient	Baffle airflow into the water side If your screw chiller capacity does not fall short of your vendor's opinion (after taking into account the actual BPH, carcass size, water flow and temperature and ice in-feed rate), then check the air bubbling through on the carcass side and water side. If the latter is significantly higher than that on the carcass side, and your chiller has an airflow system in which the two air headers feeds from the same compressor, then you need to baffle the flow of air in the pipe leading into the water side. This can be done by sandwiching a thin plastic sheet (such as a plastic folder cover punched with a number of 1 inch dia holes) between the flanges that feed into the water side header. This will throttle airflow into the water side and divert more air into the carcass side. Do not throttle too much – you still need agitation of the medium.
5	I **process birds sourced from several contract farms**. Some days chilling results are very poor. Why only on some days when on other days it is not so bad?	Refer figure 3. On your bad days you are probably sourcing birds from different farms with wide variance of age-group or aggregate variance resulting in a higher number of larger birds. You can solve this to some extent by improving your sourcing roster.
6	My **Un-loader supports** broke again. Why do they break so often?	This problem occurs only in chillers having fixed un-loaders (both screw and un-loader being connected to one drive). The principal causes are (a) You are trying to unload more carcasses per hour than the un-loader is designed for i.e. your operating BPH is much more than your rated BPH. If you increase the speed, the

		un-loader may cope, but you will lose dell time (b) You are processing much bigger birds than your plant was designed to do. (c) you have increased your dwell time so much that the un-loader arm is facing physical resistance owing to the hard packed carcasses at the unloading point The common solution is to add more screw chilling capacity. But if you expect that owing to market conditions you may again and again create the above conditions then you are better off with independently driven un-loader. Check with your vendor whether he can modify your un-loader the next time you add a shell and screw combination in a bid to expand.
7	Some of the **carcasses fall back** into the chiller from the un-loader. Shall I **adjust the un-loader angle** to improve matters?	This is normal. The phenomenon gets accentuated when you are attempting to increase dwell time beyond design levels. On no account must you fiddle with the un-loader angle. It is factory-set for optimum results. Fiddling with the angle will create uneven torque load and likely cause accumulation of carcasses and severe mechanical damage as explained in section 9.1
8	I would like to **measure the actual dwell time**. I have already set the speed as low as possible, consistent with this article.	Tie a coloured ribbon to a carcass and manually drop it at the input end. Count the number of minutes elapsed before it emerges at the output end. Repeat this exercise several times and calculate the average. Compare this figure with the screw speed setting using the following calculations. The pitch of a typical screw chiller flight is 800mm. Count the number of revolutions the screw makes in a given time by observing the edge of the flight as visible at the output end. Divide the length of the chiller by flight pitch(800mm) and you will arrive at another measure of dwell time.
9	I have installed **a meter** alongside the valve **in the chilled water inlet** of my screw chiller. How can I use its readings to ensure correct chlorine dosing and comply with the 2.5 litre per Kg standard?	There are two types of meters. The first gives you the aggregated reading of kilolitres of water that has passed from one reading to the next. This is the wrong type of meter for a screw chiller and it will not help you perform the tasks you set out to do. The second type is a flow rate meter giving you real-time instantaneous reading of flow rate in litres per minute. This is the one to install. Litres per minute related to BPM x average carcass weight will give you instant setting ability.
10	**Carcasses get bruised** because the line clearer/bird un-loader is located quite high	If you do find your carcasses are bruised, I cannot find fault with your observation. But bruising seldom occurs because of the reason you cite. The un-loader is generally located close to the ceiling, which in your plant should be at +4300 mm from the finished floor level. When this is so, the frame top of the un-loader would be at +4230mm and the bottom of the un-loader frame would be at +2320mm. The upper rim and top of screw flight of the 2100mm dia screw chiller on 500mm legs would be at +1460mm and +2200mm respectively. When a second chiller is added, the frame top and flight top of the one immediately below the un-loader would be at +1960 (1460+500) and 2700 (2200+500)mm respectively. It would then leave a leeway of a mere 360mm (2320-1960) between the bottom of the un-loader and top of the chiller frame. This space is essential for the chute. This is why the un-loader is mounted with the hock point at +3750mm above FFL and bottom of frame at 2320mm. You may get the un-loader lowered by 500mm if you are using only one chiller at present. But when you add the second chiller, you will have to raise the un-loader back. Bruising is probably occurring in your plucker or at the farm where your birds are harvested. Examine the carcasses at the bleeding point or after plucking – harvesting damages should be visible. Check your plucker – if the setting is too tight, loosen it. If the fingers are worn out, change them. If your plucking performance deteriorates on loosening the plucker finger, your scalder size is too small
11	The chiller **bath gets dirty** very rapidly. Carcasses do not look clean after chilling. Water turns pink or red very rapidly.	If the water appears red, your bleeding time is probably insufficient. Set bleeding time at 3 minutes if you perform halal killing or 2 minutes if you perform machine killing. Calculate the bleeding time according to your actual BPH, not your design BPH! Bleeding time also depends on breed, physical condition of carcasses, degree of stunning and other factors. It helps to maintain an inventory of additional shackles and chain and be ready to increase the bleeding time by repositioning your corner wheel to get optimum results. What was that? Why not set the bleeding time to 4 minutes or more? There is a very small time window from killing to plucking. Rigor mortis sets in so rapidly in poultry that if you do not pluck before 6 or 7 minutes from the time you kill, plucking becomes very difficult. You do not have the luxury of increasing bleeding time much beyond 3 minutes!
12	**Shelf life** of fresh-chilled	Are you using red water chiller system? Get rid of it.

	carcasses from my plant is too low	With your red water chiller you can get carcass temperature of as low as 2 decrees C and in-plant tests may show low bacterial activity. But when they are sold as fresh-chilled then under the uncertain cold chain conditions of South Asia they deteriorate rapidly. On the other hand frozen chicken from a red water chiller plant have a reasonable market acceptance because the post sale deterioration blame cannot be pinned on the processor. If your market is mainly fresh-chilled and you have adopted a technology which works in an essentially frozen sale market, then you have mixed chalk with cheese!
13	**Shelf life** of fresh-chilled carcasses from my plant is too low	Is your chlorine dosing correctly set? Read section 9.7 for possible errors in your setting.
14	Carcasses emerge with **ice in their body cavities**. This causes malfunction in the automatic grading line that follows the screw chillers	You are probably adding crushed ice instead of flake ice. Crushed ice contains non-uniform pieces and the larger ones do not melt in the medium. You are probably adding too much flake ice. Set the control of your in-line flaker to deliver at a lower rate. You may be producing flake ice, but your flaker is not located directly above the screw chiller to automatically dose ice in real time and consequently you are storing flaked ice and manually delivering into the screw chiller. Flake ice tends to form lumps if stored at temperatures above -10 ^{o}C.

Readers are welcome to send their comments, critiques, observations and suggestions to the author at rajalok@gmail.com or alok@aptec.in. The author gratefully acknowledges valuable information inputs from various industry professionals and plant managers.

[1] All international standards that I have come across relate 2.5 litres of water to kilogram of carcass weight except Indian standards which relates 2.5 litres to one eviscerated carcass (carcass weight apparently not relevant).