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# A STUDY OF THE PRACTICAL & ECONOMIC CONSIDERATIONS ASSOCIATED WITH HIGH VELOCITY & LOW TEMPERATURE AIR STREAMS FOR THE CHILLING OF BEEF

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## 1. GENERAL CONSIDERATIONS

Whereas it is simple enough to design a chiller, operating at a temperature of $-1^{o}C$ and an air speed of about one metre per second, that will reduce the deep round temperature of 120/140 kg sides of beef to $7^{o}C$ in a twenty four hour cycle, meat so chilled suffers a shrink of about 1.4 per cent and the thinner parts and much of the exterior of the meat, is at a temperature of between $-1^{o}C$ and $+2^{o}$ at the end of the process.

Meat in this condition is not acceptable for a modern high speed boning operation since it slows the production rate and engenders labour disputes. It was therefore necessary to find a chilling programme that would allow time within the 24 hour cycle for temperature equalization in the meat before boning. Equally importantly it was expected that this would also lead to a considerable reduction in shrink losses.

## 2. PRELIMINARY TESTS

2.1 In October 1974 The Union International Co. Ltd. engineering department asked Mr. Colin Bailey of The Meat Research Institute to arrange a meat chilling test in the Institute's experimental wind tunnel. In this test a side of beef was chilled for six hours at $-15^{o}C$ with an air flow rate of two metres per second followed by eighteen hours at $0^{o}C$ and the same air velocity. The results of this preliminary test (shown in figure 2.1) were sufficiently encouraging to justify a further test on twelve carcasses of beef to confirm the low carcass weight loss and the commercial acceptability of the product.

2.2 In June 1975 a test was made on twelve beef carcasses in a recently constructed chilling facility at the Gloucester abattoir of British Beef Company Ltd., to whom our thanks are due for their co-operation. The twelve right hand sides were blast chilled for six hours at $-15^{o}C$ and at an air speed over the meat surface of 0.5-1.5 metres per second. After six hours the refrigeration was discontinued and the meat temperature allowed to equalize as the air temperature in the chamber rose slowly to $4^{o}C$ after a total of eighteen hours. Refrigeration was then applied intermittently to keep the temperature between $0^{o}C$ and $4^{o}C$. The twelve left hand sides were chilled in a conventional forty eight hour cycle beef chiller. Temperature gradients of different parts of the carcass during cooling are shown in figure 2.2. The comparative evaporative losses during cooling by the two systems were blast chill 1.275 per cent, conventional chill 1.940 per cent. The condition of the meat at the completion of the blast chilling was satisfactory and, in some aspects, preferred to the meat chilled over forty eight hours.

## 3. TESTS CARRIED OUT AT THE RIVERSTONE MEAT COMPANY'S WORKS IN N.S. WALES, AUSTRALIA

3.1 The experimental blast chiller at Riverstone was designed to hold forty sides of beef of average weight 127 kgs. The evaporators were fitted above the rails at each end of the room and the fans were arranged to discharge into a plenum chamber from which the cold air flowed through ajustable slots above and parallel to the rails. The total suface of the evaporators was 540 square metres, giving a nominal capacity at $10^{o}C$ $\Delta t$ of 342 MJ. per hour. Eight fans of 1.5KW each were installed with a total rated air flow of 94,100 cubic metres per hour against a design pressure of 24mm W.G. (2.35m bar).

3.2 Refrigeration tests

### 3.2.1 First series

A series of tests was made, each on about forty sides. Washed sides of beef were weighed and loaded into the pre-chilled chamber, with the air off and refrigeration then applied. Air velocity over the round was measured at 2 mts. per second and under these conditions it took, in general, up to two hours to achieve an air temperature of $-15^{o}C$. Refrigeration was continued at this level until a temperature of $25^{o}C$. was achieved in the deep round, at which point fans and refrigeration were stopped and the temperature of the meat allowed to equalize over the balance of a twenty four hour cycle. In the last half hour the fans were re-started, with hot gassing of the refrigeration coils, to dry off the meat surface before boning. The average shrink during cooling, in the fourteen tests in this series, was 1.265 per cent of the hot washed weight, confirming the results obtained at Gloucester. Cooling curves from one of these tests are shown in figure 3.1.

### 3.2.2 Second series

A second series of tests was done, in the same experimental chamber, but loading only twenty sides per test in order to reduce the time required to achieve the desired air temperature of $-15^{o}C$. which, under these conditions, took about ten minutes. In these tests it was found that optimun shrink was obtained using $-15^{o}C$. for the first hour and that the faster this temperature was achieved the better. The temperature used for the remainder of the blast period was less critical, as regards shrink, although the total duration of the blast chill period did affect the total shrink. Table 3.1 shows the effect of varying the air temperature on the shrink. In these tests both washed and unwashed meat was chilled and meat was weighed before and after washing. Tests made on unwashed meat showed a lower shrink than washed meat, but the residual water on the washed beef evidently conferred some protection, since the weight loss of washed beef, referred back to the unwashed weight, was only of the order of 0.2 per cent compared to 0.5 per cent on beef chilled directly without washing. The average shrink of the washed beef in all these tests was 1.02 per cent. Meat washed and drained for nine minutes before weighing, shrank only 0.67 per cent during chilling. Cooling curves for one of these tests are shown in figure 3.2.

### 3.2.3 Determination of the refrigeration load

The refrigeration loading during these tests was calculated on the basis of the enthalpy changes in the dry air across the evaporators, to which was added the latent heat of condensation and freezing of the moisture evaporated from the meat (shrink). The air velocity across the face of the evaporators was measured by means of a vane anemometer (Sharpe and Masin). The air temperatures before and after the evaporators was measured with copper-constantan thermocouples, via a switching box with five seconds for each reading. Temperatures were recorded on a charge recorder (Yakogawa). From this data enthalpy changes and mass flow rates were calculated which, together with measurement of the condensate from the defrosting of the evaporators, enabled the calculation of refrigeration loads on an hour by hour basis.

The total refrigeration load, per body of 250 kgs average weight, as used in the final works design was: first hour 19.1 MJ; second hour 13.3 MJ; third hour 9.6MJ; fourth hour 8.4 MJ. After making allowances for fan loading, solar gain and infiltration, these figures were still inexplicably high, totalling up to three times the actual heat extracted from the meat; no explanation of this was found.

3.3 Boning tests

Comparative boning tests were made, on meat chilled in the first test series, compared to paired sides chilled in the works conventional chillers. Alternative left and right sides from successive carcasses were blast chilled, alternative right and left sides chilled conventionally to give a balanced test. The results of boning nearly twenty five tonnes of beef to regular commercial fat trim standards are shown in table 3.2.

Based on the hot, washed, killing floor weight the yield of trimmed meat was:

- from blast chilled meat 66.8 per cent;
- from regularly chilled meat 66.1 per cent.

On the cold meat basis the respective figures were:

- blast chilled 67.6 per cent;
- regular chilled 67.9 per cent.

Evaporation losses from the meat continued after removal from the chillers to the boning room and these further losses were greater in the case of the blast chilled meat than in the regularly chilled meat, as could be expected; nevertheless the revenue increase from blast chilling was of the order of one per cent.

## 4. DESIGN OF A BLAST CHILLING FACILITY FOR A LARGE MEATWORKS AND ANALYSIS OF ADDITIONAL CAPITAL COSTS OVER CONVENTIONAL CHILLING FACILITIES AGAINST ADDITIONAL REVENUE POSSIBLE

4.1 From the information obtained in 3.2.2 it was decided that the most suitable chilling programme would be:

- one hour at $-15^{o}C$; air velocity over meat 2 metres per sec.;
- three hours at $-12^{o}C$; air velocity over meat 2 metres per sec.;
- seventeen hours for temperature equalization; no air movement.

4.2 Two methods of applying this programme were considered:

- a chilling tunnel for the first hour at $-15^{o}C$; the sides then transferred to a chamber at $-12^{o}C$, fitted with "walking beams" for the second hour, then conveyorized to regular chambers for the remainder of the chilling cycle;
- a first chamber fitted with "walking beams" for the first hour at $-15^{o}C$ all the remaining arrangements as in the first option.

The second option was adopted on the following grounds:

- greater flexibility; regular chilling cycles could be employed if desired;
- reduced space requirements; a chilling tunnel "snake" required wider spacing between the rails than a "walking beam" system.

4.3 On the design option chosen all costs, other than for the provision of additional refrigeration equipment, were identical for either regular or blast chilling systems. For a facility to handle one thousand head of beef per day the comparative costs and savings were as follows:

- additional capital cost for blast freezing compared to conventional chillers; £480,000
- increased revenue from additional meat yield as per 3.2.3;

| | |
|---|---|
| average boning yield conventional chilling 68 per cent | |
| average carcass weight 250 kgs | |
| average meat value £1.32 per kg | |
| additional yield from blast chilling 0.7 per cent | |
| additional revenue per 1,000 head | £1.570 |
| less additional energy costs per day | £ 340 |
| net daily saving (1,000 head) | £1,230 |

On the basis of 1,000 head per day; 250 days per year and 80 per cent overall use, the total annual kill would come to 200,000 head and the increased yearly revenue would therefore be £246,000 - a 51 per cent return on the additional capital investment of £480,000.

TABLE 3.1 EFFECT OF AIR TEMPERATURE ON SHRINK

| Air temperature (centigrade) 1st Hour | 2nd Hour | Number of tests made | Percentage shrink 1st hour | 2nd to 4th hour |
|---|---|---|---|---|
| -15 | -12 | 9 | 0.50 | 0.44 |
| -15 | -9.4 | 1 | 0.51 | 0.51 |
| -15 | -6.7 | 2 | 0.58 | 0.56 |
| -12 | -12 | 2 | 0.48 | 0.58 |
| -12 | -9.4 | 1 | 0.54 | 0.46 |
| -9.4 | -9.4 | 1 | 0.60 | 0.45 |

TABLE 3.2 SUMMARY OF BONING TESTS (RIVERSTONE 1979)

| Chilling method | Blast chiller | Conventional chiller |
|---|---|---|
| Hot washed weight | 12418.3 kgs | 12404.7 kgs |
| Weight ex chiller | 12269.3 kgs | 12078.0 kgs |
| Chiller shrink | 1.20 % | 2.63 % |
| Weight as boned | 12249.1 kgs | 12067.0 kgs |
| Total shrink | 1.36 % | 2.73 % |
| Trimmed meat recovered | 8299.0 kgs | 8204.0 kgs |
| Yield of trimmed meat: | | |
| On hot meat basis | 66.8 % | 66.1 % |
| On chilled meat basis | 67.6 % | 67.9 % |

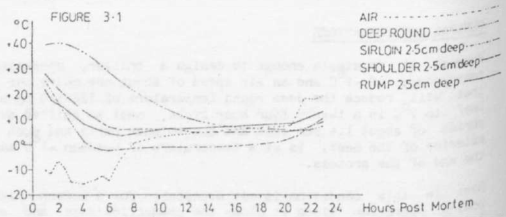

FIGURE 3·1

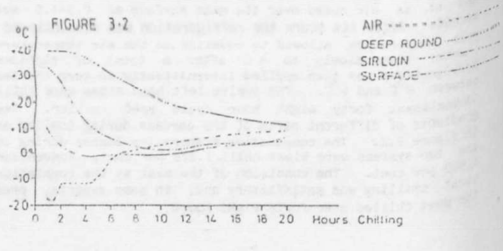

FIGURE 3·2



FIGURE 2·1

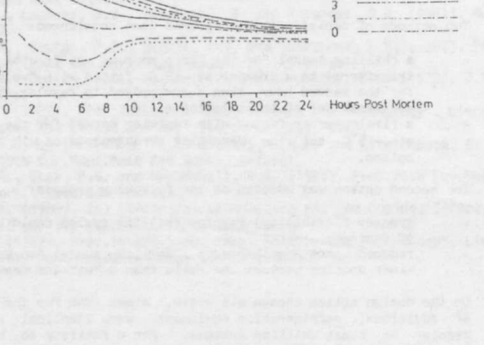

FIGURE 2·2