ACCELERATED PROCESSING OF BEEF

By

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Introduction

Meat handling in modern abattoirs can be described as an "interrupted flow" system. That is, in a meatworks which breaks down the carcass for packing into cartons, the overnight (or longer) chilling phase, introduces a substantial delay in the flow of product.

Continuous flow processes are generally recognised as being more efficient than batch processes, and in times of increasing pressure, to become more efficient all round, it is not surprising that the meat processing industry should seek to explore the possibilities of continuous flow. Accelerated processing of carcasses (commonly called "hot-boning"), is just such a possibility.

The basic concept of accelerated processing is that killing, dressing, breaking down and packing of the meat, shall all be done within the span of a single working day.

Potential advantages

Direct refrigeration

Because the bones of the carcass and the unwanted trim are not to be cooled with the meat, there is an immediate within-abattoir saving of about 30% in the direct refrigeration energy required for chilling. In conventional meat processing, the movement of carcasses into and out of chillers requires large doorways, which allow the egress of substantial quantities of cold air and the ingress of substantial quantities of warm and usually moist air. The heat and moisture load incurred, as a result of the use of conventional chillers, is a substantial addition to the amount of refrigeration energy required to cool the whole carcass or beef side. If, on the other hand, a carcass were able to move directly from the slaughter floor to the breaking down area, the need for chillers with large doorways could be eliminated altogether. Although it is not possible to calculate the refrigeration energy saved, as a result of this manoeuvre, there have been estimates based upon CSIRO research, which indicates the saving could be of the order of about 10% of the refrigeration energy normally used. Estimates made in the United States have indicated that the overall refrigeration energy savings, resulting from the use of accelerated processing, as against conventional processing, is of the order of 50%. It should be stressed however, that at the present time none of these energy savings has been conclusively proven.

Refrigerated space

A CSIRO survey has indicated that Australian abattoirs are extremely generous in providing chiller space for carcasses. There are about 3.5 cubic metres of space per body, compared to about 2 cubic metres provided in the United States of America. The actual space occupied by the meat from the average head of cattle slaughtered in Australia, is about 0.16 cubic metres. This is less than 5% of the volume we presently give to chilling the whole carcass. Clearly then, were accelerated processing to be adopted, there is the potential for reducing the amount of refrigerated space required, by a very large proportion. In the case of cuts to be packed and distributed as chilled beef, it is likely, for reasons to be discussed later, that some preliminary chilling, as individual cuts, will be required, prior to packing into the carton for final cooling down to about $0^{\circ}C$. However, the space required for this operation would be greatly reduced over that required for the chilling of the whole side or carcass. If of course, the meat were to be packed and distributed as frozen product, it is possible that chiller space could be eliminated entirely. This of course assumes a perfect world, and in fact there would need to be some stand-by chiller space to cope with stoppages during the day's production. In addition to this, some operators may prefer to give the carcass an initial surface chill to harden up the fat and make subsequent trimming and slicing an easier task. This too would require some refrigerated space, although the residence time in that area would be much shorter than the conventional 16-24 hours, again indicating that chiller space requirements could be very substantially reduced.

Yield

During conventional chilling, carcasses lose moisture, and in an average meatworks the loss of carcass weight from this cause amounts to about 2.4%. If one makes the very reasonable assumption that this moisture loss comes from the edible tissue and not from the bone, and re-calculates the loss on a boneless meat basis, the yield deficit rises to about 3.5%. Accelerated processing offers the potential to substantially reduce this overall weight loss. Small scale investigations into this aspect of accelerated processing, have produced somewhat conflicting results. A United Kingdom study, based upon only 16 animals, came to the conclusion that there was not a significant increase in overall edible lean meat achieved by hot-boning. On the other hand, in a study involving 10 beef cattle, Brazilian researchers claimed that the increase in yield is about 1.7%, due to accelerated processing. Trials in New Zealand have yielded results from actual commercial operations. With prime steers, a yield advantage of 3% in favour of sides boned direct from the slaughter floor, was achieved At the same establishment, 161 low quality cow bodies were subjected to a similar trial. Boning took place after a 3-4 hour chill and the resulting yields were virtually identical to those obtained conventionally.

This contrasts with the results reported by another New Zealand company, with bobby calves and manufacturing cow beef, where, after a 2½-3 hour pre-chill, a 4-4% better yield was recorded for the bodies which were hot-boned.

Another aspect of improved yield which has been claimed, is that vacuum-packaged hot-boned meat exudes less drip than is the case with conventionally processed meats. In the above cited trial in a New Zealand meatworks, the drip recorded in hot-processed vacuum-packed beef, was one third that recorded for conventionally processed vacuum-packed beef.

Processing time

Clearly, the aim of accelerated processing is to compress the overall operation from killing to packing the meat in the final container for despatch within a much smaller time frame. The actual time savings will depend upon whether any particular operator deems it necessary to pre-cool the carcass meat before proceeding to the deboning operation.

Manpower

In conventional processing, virtually all meatworks manually load and unload the batch chillers, using at least one man per 100 beef bodies. If carcasses were to be taken directly from the slaughter floor to the boning room, one could contemplate that a powered rail, or gravity rail system, would achieve this, without manual intervention. Even if a pre-cooling period were decided upon, it would seem sensible that carcasses should move through some form of chilling tunnel on a continuous driven rail system, prior to introduction to the boning area, after the necessary pre-cooling time. Whatever the final procedure adopted, it would be realistic to anticipate a significant saving in manpower required in the overall operation.

Potential difficulties

Microbiological status

Fresh warm meat, with its moist surface and abundance of nutrients, provides a very attractive environment for the growth of bacteria. Because accelerated processing leads to the creation of large numbers of freshly exposed moist meat surfaces, there exists a much greater potential for the growth of undesirable organisms, than is the case with conventionally handled carcass meat. As you know, in handling carcass meat, cold air movement over the carcass in a chiller, leads to drying of the surface of the meat, which in turn produces an environment inhibitory to microbial browth. With accelerated processing however, meat is to be taken warm and moist from the carcass and in many

cases placed into boxes prior to cooling. Under these circumstances, the freshly exposed surfaces of the meat cannot be dried by the circulating cold air, and thus one of the factors controlling microbial growth is eliminated.

Under these circumstances, microbial growth has then to be controlled by temperature alone, rather than a combination of temperature plus surface drying. It therefore becomes critical to reduce the temperature of the meat in the carton to a figure where at least the food poisoning organisms will have had no opportunity to increase in numbers. Recent experiments at the CSIRO Meat Research Laboratory have defined the conditions under which meat packed into a carton at any given temperature, must be reduced to 7°C and prevent the growth of potential food poisoning bacteria. The results of this work are summarised in Figure 1, from which it can be seen for example, that meat packed at a temperature of 35°C must be cooled to 7°C at the centre of the carton within 5 hours, or, if pre-chilling has been undertaken and the meat temperature is 25°C, 7½ hours can be allowed for cooling (Fig 1).

Primal cuts for the chilled meat trade are likely to be vacuum packed, and should perhaps be cooled in a different manner. One would envisage in this situation, the cooling of these cuts as separate entities in some kind of chilling tunnel, prior to their being boxed for final cooling in a carton chiller.

Tenderness

Accelerated processing introduces the risk of greatly increasing the toughness of meat. Before rigor-mortis is complete and the muscles have set, there always remains the capacity within those muscles for contraction. Any muscle contraction which does occur after death is permanent because post-mortem muscles do not relax again. This is important because the greater the degree of contraction in a muscle, the tougher will be the meat.

Whilst the muscles still remain attached to the skeleton, they are to a certain extent restricted in the amount of contraction which may take place, although in conventionally-hung animals (where the carcass is suspended from the Achilles tendon) considerable latitude for contraction still exists in the hindquarter muscles and in the striploin. However, in accelerated processing, where the meat is removed from the skeleton very soon after the death of the animal, there is an even greater latitude for muscle contraction and that latitude is exhibited in a greater number of muscles. A further complicating factor is that the greater the vigour with which one cools meat in its pre-rigor state, the greater the contraction which can be induced in the muscles. Ultimately, one may get contractions of such

a magnitude that the muscle is only about half of its original length. This means a very dramatic increase in terms of meat toughness. Any accelerated processing procedure must therefore include treatments which will minimise or eliminate any meat toughening that might otherwise occur.

Handling problems

Hot meat is sticky, sloppy and difficult to handle, and because of this there are a number of potential problems in both boning and slicing. Reported experiences of these problems will be discussed later.

There is a further potential problem, which has not to my knowledge been investigated, and that is that the rendering raw materials will be close of body temperature when they are available for processing. Under these circumstances, it will be necessary to process such material as quickly as possible, or alternatively, to adopt procedures which will inhibit the breakdown of fat and the microbial degradation of the lean tissue. The process of acid stabilisation of the rendering raw materials, might very well be appropriate to this situation.

Cooling of hot-boned meat

As has been previously mentioned, the cooling regimes required for the safe handling of hot-boned manufacturing meat, packed into 27.2 kg cartons, has been extensively investigated. The major problem under these circumstances, is to ensure that at the geometric centre of the carton of meat the temperature is reduced sufficiently quickly to prevent the growth of food poisoning bacteria, such as Salmonella. Tests done many years ago by the Meat Research Laboratory, showed that with conventional blast freezing facilities, such as are used in most Australian meatworks, the temperature at the centre of a carton packed with meat at 35^{o}C, remained sufficiently high to allow an increase of about 1,000 fold in Salmonella organisms. This of course is an intolerable situation.

The solution to this dilemma involves either pre-cooling the carcasses to a lower temperature before boning, or, in adopting additional cooling methods to achieve the temperature reduction required. For beef, the slow rate of cooling of meat at the deep butt, makes it impractical to consider a pre-cooling period for the purposes of reducing meat temperature sufficiently to allow a longer cooling time in the carton, chiller or freezer. Therefore, some alternative method of freezing, or some aid to freezing, would have to be adopted.

Aids to freezing which have been investigated and successfully used, are the addition of carbon dioxide, in solid form or as a snow, to the meat when the carton is half full, and before proceeding to fill the carton, or the use of liquid nitrogen in a cryogenic tunnel. The amount of solid carbon dioxide which would need to be added to a carton of meat, packed at a temperature of 35^{o}C and cooled in a conventional blast freezer, with air temperature of minus 30^{o}C and air velocity of 5 metres per second, is calculated to be 1.6 kgs. This should allow the meat in the carton to be reduced to 8^{o}C in the required 5 hours. However, little experience of this procedure has been obtained and a physical check of the cooling rate would be wise.

Although liquid nitrogen freezing has been proposed, the effectiveness of this technique is still uncertain. Undoubtedly, if the individual meat pieces were put through such a cryogenic tunnel prior to packing, there would be a significant effect on the amount of heat required to be removed in the subsequent blast freezing stage. On the other hand, if a carton is to be packed to a given visual lean, crust freezing of individual meat pieces in the cryogenic tunnel may make it difficult to estimate fat content. In addition to this particular problem, the economics of the use of liquid nitrogen are not yet known, and the supply of this material is likely to be restricted to the major cities, if it is to be obtained at a reasonable cost.

Alternative methods of freezing, particularly using plate freezers, have been recommended as providing the best immediate solution to the problem of cooling hot boned meat sufficiently rapidly. The proposal for using plate freezers envisages the meat being packed in a polythene film in a carton-sized aluminium mould. Under these circumstances, meat packed at 35^{o}C can be cooled sufficiently rapidly if the plate freezer refrigerant temperature is minus 35^{o}C. If, on the other hand, those moulds were to be placed in an air blast freezer with an air temperature of minus 35^{o}C, the initial meat temperature could not exceed 29^{o}C, or alternatively, if the meat were in a carton in a blast freezer with minus 35^{o}C air, the initial meat temperature could not exceed 25^{o}C. It can be seen then, that there are some difficulties remaining in achieving the time temperature specifications laid down by the Bureau of Animal Health for the cooling of hot boned meat, particularly if the meat is taken from a carcass which has had essentially no pre-cooling.

One development which may be significant remains to be explored. If carcasses, as they leave the slaughter floor, are subjected to a hot water decontamination process, whereby they are exposed to water at about 80^{o}C, between 99 and 99.9% of all bacteria contaminating the carcass are eliminated. If this procedure were adopted and thereafter the product was subject to all possible precautions to prevent re-contamination, it is likely that the hot boned product could be cooled considerably more slowly than is required at the present time, and still yield a microbiological status better than the meat which currently enters the market place. It should be stressed however, that this prediction has yet to be proven.

Overcoming tenderness problems

One thing that is now certain, is that the inherent potential for meat toughening, as a result of accelerated processing (hot boning) can be eliminated. By adopting recently developed techniques for electrically stimulating the carcass within about one hour of the death of the animal, the risk of meat toughening due to hot boning and subsequent cooling, can be ignored.

The principle behind the technique of electrical stimulation, is that electrical energy is supplied to the carcass in order to make the muscles work extremely hard over a short period of time. Because the animal has been killed and has no blood supply remaining, the muscles quickly go into a state which resembles an advanced onset of rigor mortis. The work done in the muscles produces large quantities of lactic acid within a matter of minutes and this results in a fall in the pH of the muscles to values close to that which would have normally occurred within 16 or 20 hours if the carcass did not receive stimulation. By the time the lactic acid concentration in the muscles is such that the pH is about 6, the capacity of the muscles to undergo pronounced shortening due to the exposure to cold, has virtually disappeared. Therefore, either the whole carcass, or the muscles taken from the carcass, can be exposed to extremely cold conditions without significant toughening of the meat.

Electrical stimulation can be accomplished in a number of ways, and commercial equipment is available. For the purposes of hot boning, CSIRO recommends that meatworks install high voltage automatic stimulation systems, which subject the carcass to electrical current provided by a pulsed input of electrical energy, supplied at a potential difference of 600-800 volts. Whilst the pulse rate is not especially critical, mains frequency is too high and heating problems may result in melting of the Achilles tendon, in which case the carcass will fall to the floor. The most commonly recommended pulsing is 14.3 per second. Electrical energy is applied, depending on the time after slaughter, for between 45 and 90 seconds. It is current CSIRO recommendation, that the carcasses then be left for 1-2 hours prior to the beginning of boning, to establish an advanced state of rigor mortis. This assists boning by firming up the otherwise fairly sloppy hot meat.

Every existing works will have different problems in installing stimulation equipment. Some may even need to delay stimulation until after splitting. Figure 2 summarizes CSIRO's recommendations for various circumstances. To determine the engineering needs to meet these electrical specifications, it is suggested that the CSIRO Meat Research Laboratory or an appropriate private consultant be approached.

It must be emphasized that the major effect of electrical stimulation, is to prevent meat being toughened by cold shortening. It is not a means of inducing significant increased tenderness in any particular cut of meat, and it is erroneous to assume that old animals

can be made more tender by the use of electrical stimulation. In short, electrical stimulation preserves the degree of tenderness inherent in the animal as it is killed, it does not confer significant tenderness in its own right.

There are no fully satisfactory devices available, which will indicate the degree of effectiveness of electrical stimulation on any given carcass. One of the most obvious effects of electrical stimulation is that the carcass muscles become so exhausted, that the usual twitching of certain muscles on the body, is absent. Perhaps the only objective means of determining effectiveness of stimulation available at the present time, is to measure muscle pH. For stimulation to have been effective, the pH of the muscle, one hour after stimulation, should be around 6. Readings higher than about 6.2 should be regarded with considerable suspicion.

Whilst there are several stimulation systems available, and whilst it is clearly in the best interests of hot boning, to accomplish stimulation as early as possible after the death of the animal, there may be complications if it is done prior to hide removal. The stimulation treatment will so exhaust the muscles, that the electrical spine stiffener used in conjunction with downward hide pullers, will no longer be effective, and broken backs will occur in much higher than normal numbers. It is advisable then, if downward hide pullers are in use, to locate the stimulator after hide removal.

Miscellaneous comments

Boning

The commercial trials which have been undertaken, seem to have universally led to the conclusion that the boning operation in accelerated processing, is no problem. Generally speaking, it has been reported that the bones for the most part are more free of residual meat scraps, thus perhaps contributing to the better yield. Indeed, in the largest New Zealand trial known to the author, 36% less meat was left on the bones. One of the tasks said to be more difficult with hot boning, is ribbing out and the removal of some of the fore-quarter cuts. When handling primal cuts, it has been reported that there is some extra care required to prevent muscles parting at the seams.

Slicing

Those involved in hot boning trials have reported that the major difficulty associated with the technique, is in trimming and slicing. It is this factor more than any other which will probably lead to the adoption of a delay of some 2-4 hours, during which time the surface of the carcass is subjected to cold air before boning commences.

Packaging

There have been reports that hot boned primal cuts for vacuum packaging, lead to some problems with fat smearing on the inner surfaces of the vacuum pouch. Although no studies have been undertaken, it may be that under these circumstances, a clip seal system will be more attractive than a heat seal technique.

The large scale New Zealand trial elicited from the work force the comment that cartons are easier to pack with manufacturing meat, when the meat has been hot boned.

Summary

Accelerated processing has much to offer and some difficulties into the bargain. Clearly the technology is available to preserve eating quality but achieving the necessary cooling rates of cartonned meat to ensure microbiological quality may prove difficult in many works.

At the present time the approval of the Bureau of Animal Health must be secured for hot boning procedures and only one, strictly-defined procedure will be permitted for each works.

Despite the difficulties, the advantages perceived are such that hot boning is now being done commercially in Australia.

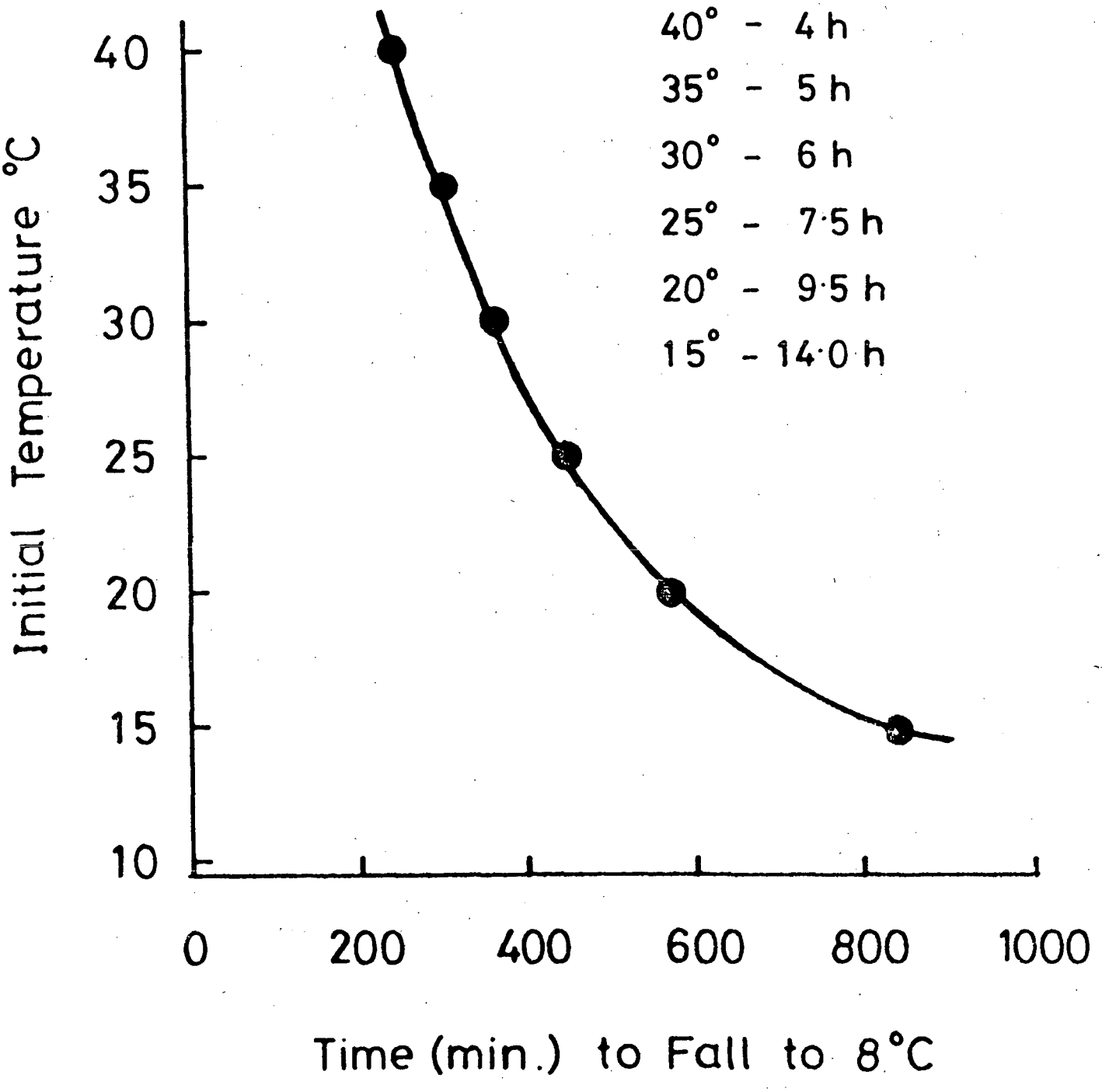
40° - 4 h
35° - 5 h
30° - 6 h
25° - 7·5 h
20° - 9·5 h
15° - 14·0 h
Initial Temperature °C
40
35
30
25
20
15
10
0
200
400
600
800
1000
Time (min.) to Fall to 8°C

Figure 1.

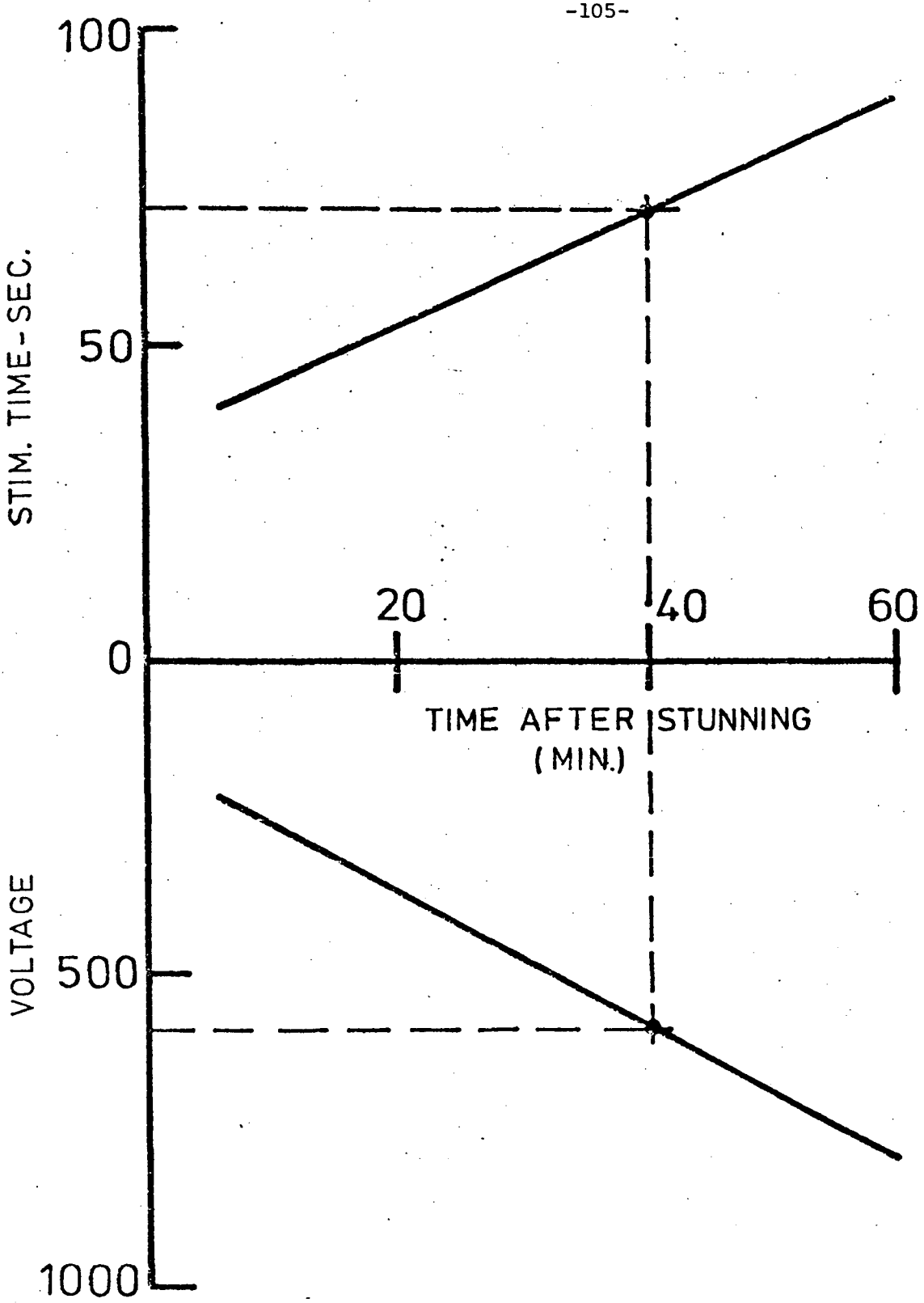

Fig. 2.

EXAMPLE :- ASSUME SPACE AVAILABLE ON DRESSING CHAIN 40 MINUTES FROM STUNNING. (INCLUDING "SMOKO" BREAKS ETC)

STIMULATION VOLTAGE REQUIRED - 600 VOLTS

STIMULATION DURATION " - 70 SEC