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Since World War II there have been a number of important innovations in milking systems for dairy cows. Changes in parlor design have included the herringbone arrangement and expansion from two rows of cows to the trigon and polygon parlor. During the 1970s advances in mechanization have provided more effective cleaning equipment, new feeding arrangements, power gates and controls, and automatic detachers all designed to increase the number of cows one operator could milk per hour with reduced physical effort and greater management control. All these developments have increased the number of options for capital investment. This analysis seeks to identify some of the more important options available to dairymen and consider their costs for herds ranging between 50 and 500 cows.

Some Recent Research Results

Research reporting on costs of alternative milking systems over a range of herd sizes is limited. Analyses of this type from the 1950s and 1960s have been outdated by more recent innovations. Often the approach in recent years has been to examine one component of the overall cost situation, or to assess strengths and weaknesses of two competing parlor types, or to evaluate recent innovations without assessing the eventual role they will play in milking system management, or to assemble parlor throughput figures for various systems without commenting on the associated fixed and variable costs.

The most comprehensive recent analysis was made by C. R. Hoglund in his Dairy Systems Analysis Handbook. In this July 1976 publication four major parlor types were assessed and general recommendations for herd sizes appropriate to each system were listed. Since specific costs by system were not reported, it is not possible to determine which system is most cost efficient when two or more systems are suitable for a given herd size. For example, three different alternative parlors for a herd size of 200 are listed as appropriate in Table 1: herringbone double 6, herringbone double 8, and 16 stall polygon. The preferred system and associated mechanization is not established.

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Table 1. EXPECTED PERFORMANCE OF MAJOR PARLOR TYPES BY HERD SIZE
North Central and Northeastern United States, 1976

Parlor type	Number of Milkers: Standard system	Number of Milkers: Mechanized system	Cows Milked/Hour: Standard system	Cows Milked/Hour: Mechanized system	Systems adapted to herd sizes of
Stall barn:					
Bucket	1,2		27		30- 60
Pipeline	1,2		34		50-150
Herringbone:					
Double 3	1	1	33	42	40-120
Double 4	1	1	38	48	60-160
Double 6	2	1	60	65	100-200
Double 8	2	1	74	75	200-260
Double 10	2	2	86	98	250-320
Rotary:					
17 Stall		2		96	280-320
Polygon:					
16 Stall		1		75	200-260
24 Stall		2		130	400-480

Source: Hoglund, Dairy Systems Analysis Handbook, 1976.

Further on in this study Hoglund focuses on three herringbone systems (Double 4, 6 and 8) and derives specific annual costs per cow for various combinations of incremental mechanization: first including power gates, then feedbowl covers and finally automatic detachers.

In summarizing his results (Table 2), Hoglund indicates that a herringbone double 4 system is "most economical" for herds up to 180 cows. Between herd sizes of 180 and 240 the herringbone double 6 is evidently the best choice and for 240 or more cows a herringbone double 8 is the optimal alternative. Hoglund is rather ambiguous about the amount of mechanization to be included in the herringbone double 4 system. For the double 6 and double 8 systems he specifies that power gates, feedbowl covers and automatic detachers should be included.

Hoglund suggests adding automatic detachers to a system only after including feedbowl covers and power gates. However, detachers will produce greater cost savings by eliminating a milker from the parlor (in any herringbone parlor larger than a double 5) than will power gates and feedbowl covers.

Several Michigan State studies (Armstrong and Bickert) have evaluated herringbone, side-opening, polygon and rotary systems separately. The parlor throughput figures presented in these studies are perhaps the most widely quoted data of this type. The cost data in the Armstrong and Bickert studies are on an "annual milking cost per cow" basis. They include such charges as depreciation, interest, repairs and insurance on capital investment, which is estimated at $15 per square foot for parlor construction and $8 per square foot for holding pen construction (1976 prices). While labor costs are estimated, specific allowance is not made for other operating costs.

Table 2. ANNUAL COSTS PER COW, THREE HERRINGBONE PARLOR SIZES AND FOUR LEVELS OF MECHANIZATION
North Central and Northeastern United States, 1976

Item	Herringbone Double 4	Herringbone Double 6	Herringbone Double 8
		Cows/Hour[a]	
Cows milked per 4 hour milking:			
Base system	124[1]	195[2]	240[2]
Plus			
Power gates	137[1]	211[2]	263[2]
Feedbowl covers	137[1]	221[2]	273[2]
Automatic detachers			
Low rate	146[1]	195[1]	228[1]
High rate	163[1]	228[1]	260[1]
Annual costs per cow:			
Base system	$137	$152	$130
Plus			
Power gates	123	145	122
Feedbowl covers	125	139	118
Automatic detachers			
Low rate	135	125	117
High rate	121	107	103

[a]Superscript indicates number of milkers in parlor.
Source: Hoglund.

An appealing feature of the Armstrong-Bickert studies is the allowance for changes in milking costs per cow as herd size changes. Hoglund bypassed the consideration of this phenomenon by examining milking costs only for those sizes of herds that could be milked in a four hour milking shift. While Armstrong and Bickert did not make direct comparisons of milking costs per cow associated with four different parlors over a range of herd sizes, it can be done because each of the four sets of costs has been calculated using the same assumptions. The following table summarizes Armstrong and Bickert's least cost milking systems compiled by examining and comparing cost figures from individual parlor evaluations.

Babson Bros. Dairy Research Service, a unit of the company which manufactures Surge milking equipment, has published several versions of a booklet entitled The Way Cows Will Be Milked On Your Dairy Tomorrow (Babson Bros. Dairy Research Service). The eighth edition, copyrighted in 1976, contains a section directed toward "economic evaluation" of several different milking systems. In an approach similar to that of Armstrong and Bickert, the authors establish a comparative factor called "cost of facility and labor/cwt. of milk" which assumes a labor cost of $4 per hour and construction costs of $20 per square foot. For some unspecified reason the cost of holding areas is ignored.

Table 3. ANNUAL MILKING COST PER COW WITH DIFFERENT MILKING SYSTEMS
United States, 1976

Parlor	Mechanization	Herd Size 50	100	200	400	600
		Annual Milking Cost/Cow				
Herringbone Double 4	None	$223	$145	$107		
Side-opening Double 2	None	228	152			
Herringbone Double 6	Crowd gate, Power gates, Detachers			112	$ 75	
Herringbone Double 8	Crowd gate, Power gates, Detachers, Feedbowl covers, Stimulating sprays				75	$ 60
Herringbone Double 8	Crowd gate, Power gates, Detachers					61

Source: Armstrong and Bickert, Dairy Science Handbook, Vol. 11, 1978.

The level of mechanization for each parlor is on an all-or-nothing basis: each parlor either has "no automated equipment" or is "fully automated" (Table 4). It is not clear what forms of mechanization are included in the term "fully automated". The evaluation leaves out herringbone double 6 parlors altogether and only considers an unmechanized herringbone double 8 parlor. Time required to complete milking is not listed.

Table 4. "COST OF FACILITY AND LABOR/CWT. OF MILK"
FOR SELECTED SURGE MILKING SYSTEMS
United States, 1976

Herd size	Side-opening double 2 No automation	Herringbone double 4 No automation	Side-opening double 3 Fully automated	Side-opening double 4 Fully automated
	Cost per cwt. of milk			
50	$1.10-1.15			
100	0.75-0.80	$0.75-0.80		
150	0.60-0.65	0.60-0.65		
200		0.55-0.60		
250		0.50-0.55		
300		0.45-0.50		
400			$0.40-0.45	$0.40-0.45
500			0.40-0.45	0.40-0.45
600				0.35-0.40

Source: Babson Bros. Dairy Research Service.

A study titled Cost-Size Relationships for Large-Scale Dairies With Emphasis on Waste Management (Matulich, Carman and Carter) includes milking as one of five "stages" incorporated into short and long run average cost curves for large-scale dairying. Milking costs, representing the level of costs that are theoretically possible, are "synthesized" in an economic-engineering approach for herd sizes ranging from 375 to 1200 cows for the Chino Basin of California. Although capital investment and labor expenses for the milking stage are presented in detail, the authors never explicitly establish a set of optimal systems based on milking costs for the given range of herd sizes. Instead, they present a series of "least-cost dairies" whose costs presumably include all five of the dairy "stages". Although the specific milking system is identified for each least-cost dairy, the costs associated with it can not be factored out in the aggregation of "total annual costs".

The authors estimate capital costs by breaking each system into structural components and assigning a constant cost factor to the amount required for construction. For example, a herringbone double 5 parlor requires 576 square feet of concrete and, at a cost of $1.20 per square foot, this represents an investment of $691. The same cost per unit is used for all parlors regardless of size. Operating costs are said to include utilities as well as labor, but the former is neither explicitly explained nor presented in the report. Allowance for insurance and property tax expenses is made in a generalized form applicable to the entire dairy operation.

The authors chose to exclude from consideration such basic herringbone parlors as the double 4 and double 6, while focusing on four types of side-opening parlors (single and double 3s and 4s), five larger-sized herringbone parlors (double 5, 8, 10, 12 and 16) and two large polygon parlors (24 and 32 stalls, respectively). Mechanization combinations fell into three discrete categories: (1) no mechanization and double-stall milking units that must be swung across the pit, (2) stationary single-stall milking units and power gates and (3) automatic detachers and automatic gates. Crowd gates were included with each combination of mechanization and wash stalls were featured with all side-opening parlors. The milking systems included with each least cost dairy, up to and including a herd size of 600, are shown in Table 5.

Table 5. LEAST COST DAIRY MILKING SYSTEMS
Chino Basin, California, 1977

	Herd Size and Parlor Type				
	375	400	450	500	600
Mechanization	Herringbone Double 5	Herringbone Double 5	Side-opening Double 3	Side-opening Double 3	Side-opening Double 3
Crowd gate	X	X	X	X	X
Swinging units	X	X			
Separate units			X	X	X
Wash stalls			X	X	X
Automatic gates			X	X	X
Automatic detachers			X	X	X

Source: Matulich, Carman and Carter.

The studies cited generally suggest that herringbone and side-opening parlors are best suited for the herd sizes up to 500 cows. Another common observation is that milking costs per cow fall as herd size increases. Although the studies have little or no agreement on the level of mechanization to be used for each parlor type and herd size, they all handle mechanization combinations in a similar fashion. This approach overlooks the possibility of differences in performance based on levels of mechanization. For instance, the Matulich, Carman and Carter study does not allow automatic detachers to be evaluated without the inclusion of automatic gates. This restriction ignores the possibility that detachers may be worthwhile on a smaller parlor when automatic gates are unnecessary or not used.

Another feature missing from all these studies is consideration of cost variability and its extent in different situations. Every dairyman is faced with a range of attainable costs associated with the milking operation. The extent to which he can achieve cost reductions and different levels of efficiency is dependent largely on his management ability. Therefore a thorough evaluation of milking systems should try to present cost ranges which are attainable under various levels of management.

Methodology for This Study

Two general approaches can be taken in the calculation of costs associated with alternative milking systems. The first approach considers costs that have actually been incurred under farm conditions. This method is superior in the respect that expenses reflect actual rather than assumed or synthetic conditions. However, the countless variables which influence performance in an individual situation cannot be distinguished or held constant to provide generalized results that are applicable to other similar circumstances. So many factors affect costs in every agricultural enterprise that the probability of all these factors prevailing for more than one situation is small. Making comparisons is therefore difficult or impossible unless a very large number of observations can be made.

Milking is a highly individualized activity in the overall dairy operation. To say nothing of parlor or mechanization alternatives, marked differences exist in milking skills, practices and conditions. The most accurate analysis of alternative milking systems for a particular dairy operation would ideally incorporate individual factors that apply only to that operation. Such precision is impossible to achieve in a generalized analysis. The intent of this study is to present dairymen with an economically feasible set of alternatives from which choices can be considered as they develop individual systems to fit their own specific circumstances.

The approach taken in this analysis is sometimes described as an economic-engineering form of budgeting. Matulich, Carman and Carter describe the economic-engineering approach to budgeting as a four step procedure:

(1) Examination of system structure through complete specification of the nature and sequence of plant operations.

(2) Specification of alternative production techniques for each stage (of production).

(3) Formation of stage production functions from tabulation of all input-output relationships, and formation of total plant production functions by summing over various stages.

(4) Development of short-run cost functions by applying constant factor prices to the production functions, and combining the short-run cost functions for various output ranges to obtain the long-run cost function. (p. 14)

In this study budgets are used to project differential future cash outflows associated with each set of milking system alternatives. The consideration of differential outflows simplifies the analysis by ignoring cash inflows (which should be constant for a given herd size regardless of the milking system chosen) and expenses not directly related to the milking system. For instance, costs associated with storing milk (bulk tank and milkhouse investment and related operating costs) are likely to vary much more with herd size, the independent variable in this study, than with the type of milking system, which is the dependent variable.

The expenses used in the budgeting procedure are intended to represent the current cost situations existing on Western Washington dairy farms in 1979 operating under good management. In light of future price uncertainty no attempt has been made to adjust the magnitude of future cash outflows for some assumed levels of inflation.

This analysis departs from traditional cost analyses in several ways. Assuming that dairymen are more concerned with after-tax than before-tax expenses and returns, the impact of federal income taxation is taken into account whenever possible. Recent changes in federal tax statutes have made all components of the milking system eligible for investment tax credit. These credits serve to reduce the after-tax cost of new capital equipment and should be included in any budget analysis. Since most operating costs are deductible as expense items they must be adjusted downward to the extent of the tax "savings" that they afford.

Another departure is to assess costs on the basis of discounted cash flows rather than amortizing fixed expenses over the useful life of the asset. The discounted cash flow approach is advantageous in that it automatically considers the time value of money and avoids the rather arbitrary allocation of depreciation and interest expenses over a series of years.

Most previous studies have treated mechanization combinations in a uniform manner with respect to specific parlor types. For example, the Hoglund study considered the same four mechanization levels for each herringbone parlor evaluated. This does not allow for the possibility that one of the parlors might prove more efficient with a lower level of mechanization than is true for other parlors. This analysis evaluates each parlor base individually with respect to alternative equipment combinations. This should simplify the assessment of costs since in most cases only one mechanization level is associated with each parlor base rather than three or four.

Past research indicates that three types of basic data are required for a budget analysis of this type: capital costs, operating costs and cow throughput figures. While it has been common to estimate capital investment by applying a constant cost factor to items like building construction per square foot for each component in a system, this study allows for economies in parlor construction and equipment installation for larger units.

Capital investment figures were obtained from a capital cost survey distributed in November 1978 among nine general and electrical contractors and milking equipment dealers in Whatcom and Skagit Counties in Northwest Washington. For each of the six parlor bases considered survey participants were asked to present a cost estimate that was as close as possible to what they would normally bid on a similar parlor contract. A set of explicit specifications was attached to the survey in order to eliminate variation in cost estimates due to differences in materials or dimensions.

Operating costs as estimated for the different milking system include the use of utilities as well as labor. In contrast to many studies, these costs were explicitly derived in this analysis. Further consideration of the procedures used to estimate operating costs and cow throughputs are discussed in the sections reporting specific results.

Alternative Milking Systems

The first and one of the most important decisions in evaluating different milking systems is the selection of alternatives to be considered. Among the most widely accepted parlor types are herringbone, side-opening, stanchion (flat) barn and rotary parlors. Only herringbone style parlors are considered because they have been demonstrated to be more labor efficient than the other three types under farm operating conditions.

The stanchion or flat barn milking system has some advantages for dairymen with limited capital, small herds and low-cost family labor. But because this system requires substantial amounts of time and physical exertion it is unlikely that the average dairyman with 50 or more lactating cows, reasonable access to capital and limited labor resources will seriously consider the construction of a new stanchion barn instead of some type of milking parlor system in most cases. From the standpoint of future expansion or resale value a small walkthrough parlor has many advantages over a stanchion system in Washington and most other regions as well.

Side-opening parlors have an advantage over herringbone parlors in that they permit individual handling of cows. While these parlors permit the dairyman to give his cows more individual attention, they are less labor efficient and more costly to construct than similar herringbones. In addition to the cost disadvantages associated with side-openers, rotary parlors have been shown to be inferior as far as cow movement is concerned. For all practical purposes the construction of rotary parlors in the United States has ceased.

The six specific herringbone-type parlors chosen for evaluation were:

1. Herringbone double 4
2. Herringbone double 6
3. Herringbone double 8
4. Herringbone double 10
5. 12 stall trigon
6. 16 stall polygon

The trigon and polygon parlors are expanded and rearranged variations of the traditional double-sided herringbone parlor. Representative floorplans for these parlors are presented in Appendix A.

The mechanization options considered may be divided into five categories:

Form of Mechanization	Purpose
Automatic detachers	Eliminates decision of when to remove milking unit and actually removes milking unit
Power gates	Eliminates manual opening and closing of gates and permits remote operation of parlor entrances and exits
Feedbowl covers	Aids movement of cows into and out of milking stalls by covering and uncovering feedbowls
Crowd gate	Assists cow movement into milking parlor
Stimulating sprays	Substitutes for manual udder stimulation

Observations by the author of each of the mechanization alternatives in various Washington parlors suggested that crowd gates and stimulating sprays do not make significant contributions to milking system efficiency. Stimulating sprays do not wash the udder well enough to eliminate the manual hosework needed for proper cleaning. Crowd gates may not be necessary or effective if the parlor is designed in the "open-end" fashion which permits cows to look into the parlor as they approach it. In colder climates where it is the practice to build a wall between the parlor and holding pen, cows may not enter the parlor as readily and the crowd gate may prove to be a good investment. However, most of Washington's dairy herds are in a warm enough climate that open-end parlor construction can be assumed. One small advantage of a crowd gate is that it effectively reduces the space in which heifers or reluctant cows must be chased around before they will enter the parlor. This becomes a problem (and an advantage of the crowd gate) at the end of a milking string. The importance of a crowd gate was directly related to the abuse with which the dairyman treated his cows. The Washington dairyman who treats his cows well will not likely save enough time to justify the investment in a crowd gate. After initial observation of their use in the fields, crowd gates and stimulating sprays were not included as part of any milking system that was subjected to further cost analysis.

Feedbowl covers and power gates play a similar role in that they reduce the time and amount of walking required by the operator to move cows into and out of stalls. Since power gates permit remote operation of parlor entrances and exits it is important to have gate controls installed at both ends of the milking pit. This reduces operator movement as much as possible. In parlors like the double 4, and those trigons and polygons where only four stalls are included on a side, the cows generally move in and out well enough that feedbowl covers are not justified. In a longer sided parlor like the double 6 where cows don't enter and exit readily, feedbowl covers may be worthwhile.

Power gates and feedbowl covers have a more important role to play in double 8 and double 10 parlors with grain feeding in the parlor. Since it is questionable whether they are worthwhile in a double 6, three levels of mechanization have been chosen for analysis on the double 6 parlor base: (1) detachers only, (2) detachers and power gates and (3) detachers, power gates and feedbowl covers. This approach is useful in two ways. First, it serves to identify which combination of mechanization with a double 6 parlor is most feasible over the given range of herd sizes. Perhaps more importantly, it illustrates to some extent the ranges in cost and feasibility which are likely to result from adding various mechanization alternatives to a double 6 parlor.

The three different mechanization options are not considered sequentially for the double 8, double 10, trigon and polygon parlors. Hopefully the range in costs and feasibility illustrated for the three different double 6 systems will provide some feeling for the amount of variability to consider in choosing among systems and what the relative consequences might be of adding or deleting a form of mechanization to or from a system.

Automatic detachers have the greatest cost savings potential of all mechanization options because they eliminate the need for more than one milker in all parlors except the double 4, where one man can usually handle the system without further mechanization or automatic detachers. Automatic detachers will be of little value to the operator who seeks to machine strip the maximum amount of milk from his cows because the automatic detacher does not allow this function.

A number of styles of automatic detachers, from economy to deluxe, are currently available. The deluxe detachers are probably more durable because of their heavier construction (featuring metal retracting arms which support the milking units rather than the nylon retracting cords on the least expensive models). These would last longer, but their much higher initial cost makes them less favorable in cost comparisons with economy detachers. It is assumed that deluxe and economy detachers have the same effect on cow throughputs. Some economy detachers require the operator to wait until milk flow from the cow starts before he can set the mechanism which ensures that the unit will be detached after milk flow stops. Parlor observations indicate that these shutoff devices can be set almost instantly after milk flow starts. A skilled operator will place the units on a string of cows without setting the takeoff device, then go back and set all of the takeoff devices in a row after having attached the last unit on a cow in a row. This requires a minimum of time.

All of the above ideas were taken into consideration when choosing the mechanization combinations to be included with each parlor base. The following eight milking system alternatives were analyzed:

1. Herringbone double 4: no mechanization
2. Herringbone double 6: detachers
3. Herringbone double 6: detachers, power gates
4. Herringbone double 6: detachers, power gates, feedbowl covers
5. Herringbone double 8: detachers, power gates, feedbowl covers
6. Herringbone double 10: detachers, power gates, feedbowl covers
7. 12 stall trigon: detachers, power gates, feedbowl covers
8. 16 stall polygon: detachers, power gates, feedbowl covers

The next three sections of this report focus on the three types of data required to calculate milking costs: fixed costs, operating costs and cow throughput rates. Fixed and operating costs are discussed one after the other because they are associated with specific parlor types rather than complete milking systems. Because operating costs are estimated on the basis of an hour of parlor use, it is helpful to determine the amount of time required for milking before considering operating costs. Therefore, the establishment of throughput rates (which are needed to estimate milking times) precedes the discussion of fixed and operating costs.

Milking costs per cow for the eight milking systems are determined in a manner that permits costs to vary with herd size. A discussion of the milking cost results and their implications for milking system management concludes this report.

Milking Time and Parlor Throughput

Milking times were established on the basis of steady state cow throughput, the number of cows that can be milked in a parlor in one hour, when all milking stalls are filled. Steady state rates do not make allowance for the beginning and end of milking when the parlor is not completely full. They also do not include the time required for holding pen changes or for milking preparation and cleanup, unless of course the parlor is full of cows while these operations are being carried out.

The length of time for a complete milking shift is therefore the sum of steady state milking time plus the time required for preparation, milking startup, holding pen changes, milking operator's breaks and cleanup, as well as any other time when the parlor is not in full operation. The advantage of the steady state throughput rates themselves is that they do not vary with the number of cows milked. The calculation of milking times for various herd sizes is made easier and more consistent by combining all the extra time for startup and cleanup with these steady state figures.

Throughput figures for various parlor and mechanization combinations are by far the most difficult data to obtain under consistent circumstances and the operating conditions experienced by farmers. Due to the countless factors which influence cow movement through the parlor, any set of throughput figures is bound to be viewed with skepticism from some point of view. Moreover, geographic variations in dairy location give rise to climatic differences which dictate different practices that can alter throughput capacities. Walled-in parlors in colder climates may deter cow movement into the milking area in contrast to open-end parlors where there is no separation between parlor and the holding area.

Among other construction-related factors affecting throughput are the routes used for entry and exit from the parlor. Straight entrance into the parlor from the holding area is advisable. If cows must turn a corner in either entry or exit it is better to have the corner placed at the exit where it might delay cows leaving the parlor rather than at the entrance where it will discourage cows from entry. While much of the milking parlor literature advocates dual return lanes which run parallel but opposite to the flow of cows into the parlor, direct observations indicate that a 90° turn out of the parlor is much more conducive to cow movement than the 180° turn required by dual return lanes.

Treatment of cows and general dairy practices also have a significant effect on throughput performance. The dairyman who is consistently gentle in his treatment of cows will create a relaxed atmosphere that is effective in maintaining cow movement. Good dairy practices may take a little extra time but certain steps must be followed if herd health and milk quality are to be maintained. Udders should be washed manually with a warm water hose and dried with towels or cloths. Teats should be dipped after each milking.

Milk production per cow and the number of milkers in the parlor certainly influence the speed at which cows can be milked. This study assumed average production of 40-50 pounds per cow per day. All of the systems considered can be operated with only one milker in the parlor.

The practice of feeding grain in the parlor undoubtedly encourages cows to enter but may also delay exit if grain is left over. The overall effect of parlor grain feeding is positive on parlor throughput under Washington conditions. The throughput ranges constructed in this study assume that grain is fed in the parlor.*

Differential grain feeding can be partially achieved when cows are grouped by production levels. The longer time required to milk a group of high producers will allow these cows to consume more grain. At the same time grouping by production should speed up milking time by reducing the difficulties which occur when one slow milking cow prevents other faster milkers from leaving the parlor.

Table 6. STEADY STATE THROUGHPUTS FOR HERRINGBONE PARLORS
Armstrong-Bickert, United States, 1976

	Herringbone Parlor Size			
Mechanization	Double 4	Double 6	Double 8	Double 10
		Cows per hour[a]		
Without detachers:				
No mechanization	37^{1}	60^{2}	74^{2}	86^{2}
Crowd gate	42^{1}	65^{2}	81^{2}	94^{2}
Crowd gate & stimulating sprays	42^{1}	68^{2}	84^{2}	97^{2}
Crowd gate & feedbowl covers	42^{1}	68^{2}	84^{2}	98^{2}
Crowd gate, stimulating sprays & feedbowl covers	44^{1}	71^{2}	97^{2}	101^{2}
With detachers:				
Automatic detachers	41^{1}	59^{1}	72^{1}	78^{1}
Automatic detachers & crowd gate	45^{1}	64^{1}	78^{1}	85^{1}
Automatic detachers, crowd gate & stimulating sprays	47^{1}	67^{1}	81^{1}	89^{1}
Automatic detachers, crowd gate & feedbowl covers	47^{1}	67^{1}	82^{1}	89^{1}
Automatic detachers, crowd gate, feedbowl covers & stimulating sprays	49^{1}	70^{1}	85^{1}	93^{1}

[a]Superscript indicates number of milkers in parlor.
Source: Armstrong and Bickert.

*Parlor grain feeding is not recommended in much of the Northeast where bunk feeding in groups based on levels of production is more common.

Table 7. STEADY STATE THROUGHPUTS FOR POLYGON PARLORS
Armstrong-Bickert, United States, 1976

Mechanization	Number of Stalls 16	20	24	32
	Cows per hour[a]			
Without detachers:				
No mechanization	87^{2}	102^{2}	117^{2}	145^{3}
Crowd gate	94^{2}	110^{2}	126^{2}	155^{3}
Crowd gate & stimulating sprays	98^{2}	115^{2}	132^{2}	161^{3}
Crowd gate & feedbowl covers	99^{2}	116^{2}	133^{2}	163^{3}
Crowd gate, feedbowl covers & stimulating sprays	102^{2}	120^{2}	138^{2}	169^{3}
With detachers:				
Automatic detachers	84^{1}	91^{1}	97^{1}	141^{2}
Automatic detachers & crowd gate	92^{1}	99^{1}	106^{1}	153^{2}
Automatic detachers, crowd gate & stimulating sprays	96^{1}	104^{1}	111^{1}	159^{2}
Automatic detachers, crowd gate & feedbowl covers	97^{1}	105^{1}	112^{1}	161^{2}
Automatic detachers, crowd gate, feedbowl covers & stimulating sprays	100^{1}	108^{1}	115^{1}	167^{2}

[a]Superscript indicates number of milkers in parlor.
Source: Armstrong and Bickert.

Two different throughput data sources have been used rather frequently in analyses of this type. Perhaps the best known figures have been published by Armstrong and Bickert (Tables 6 and 7). These throughputs were established on a steady state basis, reflecting the number of cows that can be milked per hour while the parlor is in full operation. The Armstrong-Bickert throughput rates were originally developed using computer simulations and have often been criticized as being high compared to farmers experience.

Table 8. STEADY STATE THROUGHPUTS*
Armstrong Estimates, United States, 1979

	Herringbone				Trigon			
	Number of Stalls				Number of Stalls			
Mechanization	8	12	16	20	12	16	18	22
	Cows per hour[a]							
No mechanization	37^{1}	60^{2}	72^{2}	82^{2}	70^{2}	80^{2}	88^{2}	94^{2}
Feedbowl covers	39^{1}	62^{2}	74^{2}	84^{2}	76^{2}	86^{2}	94^{2}	100^{2}
Detaching units	37^{1}	55^{1}	64^{1}	70^{1}	60^{1}	70^{1}	78^{1}	84^{1}
Feedbowl covers & Detaching units	39^{1}	57^{1}	67^{1}	73^{1}	66^{1}	76^{1}	84^{1}	90^{1}
Feedbowl covers, detaching units & crowd gates	41^{1}	60^{1}	70^{1}	76^{1}	70^{1}	80^{1}	88^{1}	94^{1}

*Cows milking 60 lb. milk/day, average efficient operator and 7-8 hours of continuous milking.
[a]Superscript indicates number of milkers.
Source: Armstrong, Trigon Milking Parlor, WREP 27, October 1979.

The other source of throughputs is a Dairy Herd Improvement Association survey (Kelso, Williams and Selvage) conducted in March 1976 by Washington State University. These figures represent actual milking times from start to finish as recorded by DHIA testers on various Washington dairy farms. Unfortunately these data were generalized with respect to mechanization, differentiating only between parlors with and without automatic detachers. They also failed to make allowance for time required for holding pen changes and delays due to complications associated with testing activities. Direct comparison with the Armstrong and Bickert results cannot be made because the definitions and time spans are so different.

A second survey was conducted by extension dairy agents in Washington during the first part of 1979. It took account of the separate milking activities making it possible to calculate steady state times comparable in definition to the Armstrong-Bickert throughput concept.

While the accepted practice has been to make point or average estimates of throughput capabilities, a more realistic approach is to include a range of estimates to allow for differences in milking skills, practices and conditions. Individual parlor observations taken from the latest Washington DHIA survey provide a great deal of insight into the variability of milking speeds attainable operating various systems. This information, along with the Armstrong-Bickert data and parlor observations made by the author, has contributed to the construction of throughput ranges for this study.

A summary of the 1979 Washington DHIA survey is presented in Table 9. Data were not obtained for polygon parlors. Average herd size and the range in sizes of herds from which these data were obtained as well as steady state throughput data are presented.

The following data were obtained on each survey record:

- Number of cows milked
- Cows milked per manhour
- Number of milkers in the parlor
- Minutes of downtime per milking (breaks, holding pen changes)
- Minutes of extra time per milking required on DHIA test day

These data provided the information needed to establish steady state throughput rates from observed milking times. Because only one-man parlors were evaluated, start-to-finish milking time is obtained by dividing "cows milked per manhour" into "number of cows milked". This provides the start-to-finish length of the milking shift in hours. Only milking time, not preparation and cleanup are included. Steady state throughputs represent milking rates only when the parlor is in full operation. It was therefore necessary to eliminate from the start-to-finish milking time any times when the parlor was not fully used. "Minutes of downtime" is converted to an hour figure and subtracted from start-to-finish milking time. Another adjustment assumes that milking startup requires five minutes for each system. A further adjustment was made for "extra time required on DHIA test day". Dividing the resulting steady state milking time into "number of cows milked" produces an estimate of actual steady state throughput rates which can be compared with the Armstrong-Bickert rates. One further issue to consider is the greater variation in milking speed which characterizes the larger parlors simply because more cows are in the parlor at a given time. Any delay in milking will result in a greater number of cows being prevented from leaving the parlor.

Table 9. STEADY STATE THROUGHPUTS ON DAIRY OPERATIONS
DHIA Survey, Washington, 1979

Herringbone Parlor	Mechanization	Number of Observations	Steady State Throughputs[a] Average	Range
			Cows per hour	
Double 4	Average herd size: 119 Range: 47-230			
	No mechanization	20	39	31-49
	Automatic detachers	10	37	27-45
	Power gates	1	30	30
	Power gates & feedbowl covers	2	33	30-36
	Automatic detachers & power gates	1	41	41
	Automatic detachers & crowd gate	1	29	29
	Automatic detachers, power gates & feedbowl covers	2	40	34-45
Double 6	Average herd size: 215 Range: 128-427			
	Automatic detachers	8	52	36-63
	Automatic detachers & power gates	5	45	41-55
	Automatic detachers, power gates & feedbowl covers	8	47	39-59
	Automatic detachers, power gates, feedbowl covers & crowd gates	1	47	47
Double 8	Average herd size: 275 Range: 194-425			
	Automatic detachers	1	59	59
	Automatic detachers & power gates	1	43	43
	Automatic detachers, power gates & feedbowl covers	6	61	46-83
	Automatic detachers, power gates, feedbowl covers & crowd gates	3	63	51-81
Double 10	Average herd size: 452 Range: 208-670			
	Automatic detachers	1	58	58
	Automatic detachers & crowd gate	1	54	54
	Automatic detachers, power gates & feedbowl covers	2	74	71-77
12 Stall Trigon	Average herd size: 97			
	Automatic detachers & power gates	1	45	45

[a] One milker in parlor.

Armstrong and Bickert estimated steady state throughput ranges for herringbone parlors equipped with automatic detachers and crowd gates. The two factors they analyzed for differences in throughput were milk production per cow and operator proficiency. The resulting high and low figures for throughputs are presented in Table 10.

Table 10. STEADY STATE THROUGHPUT ESTIMATES FOR HERRINGBONE PARLORS
Armstrong-Bickert Study, United States, 1976

Herringbone Parlor	Average daily milk production per cow	Milking speed of operator*	Steady state throughput rate	Difference in throughput rate
	lbs.		Cows per hour	
Double 4	38	Fast	54	17
	56	Slow	37	
Double 6	38	Fast	76	25
	56	Slow	51	
Double 8	38	Fast	92	28
	56	Slow	64	
Double 10	38	Fast	100	27
	56	Slow	73	

*One operator in the parlor.
Source: Amstrong and Bickert.

A final set of throughput figures were developed using the Washington DHIA data and the Armstrong-Bickert estimate (Table 11). In all cases the numbers are based on one milker operating the parlor. Estimated ranges and the average in the right hand columns of Table 11 are intended to reflect conditions existing in 80-90 percent of the parlors now operated by dairymen in Washington. A steady increase in throughput in terms of cows per hour is suggested for each of the eight parlor systems considered, both at the lower and upper ends of each range. However, the rate of increase in throughput declines as parlors with larger numbers of stalls are considered.

The actual throughput attained by individual dairymen in any of these systems will depend upon their milking skills and practices. The most proficient milkers will tend to achieve throughputs near the top of the range and less proficient operators will fall elsewhere within the range suggested.

Table 11. STEADY STATE THROUGHPUTS OF COWS
Single Operator Milking Systems, Washington State, 1979

Milking system	Armstrong Bickert 1/	1979 Washington DHIA Survey	Throughput Used Range	Throughput Used Average
		Cows per hour		
Herringbone, D-4 No mechanization	37	31-49	34-44	39
Herringbone, D-6 Detachers only	59	36-63	40-59	50
Herringbone, D-6 Detachers, power gates	59*	41-55	42-60	51
Herringbone, D-6 Detachers, power gates, feedbowl covers	59*	39-59	45-62	53
Herringbone, D-8 Detachers, power gates, feedbowl covers	72*	46-83	49-76	63
Herringbone, D-10 Detachers, power gates, feedbowl covers	82*	71-77	53-82	68
Trigon, 12 stall Detachers, power gates feedbowl covers	74 2/	-	55-74	65
Polygon, 16 stall Detachers, power gates feedbowl covers	85 3/	-	66-85	76

*Estimated for detachers only.

1/ Armstrong, D. V., W. G. Bickert, "Milking Parlor Performance," Dairy Science Handbook, Vol. 11, Agriservices Foundation, Inc., Clovis, CA., 1978.

2/ Armstrong, D. V., "Trigon Milking Parlor," Western Regional Extension Publication 27, University of Arizona, October 1979.

3/ Armstrong, D. V., "Milking Parlor Performance in the 80s," unpublished manuscript, 1979.

Table 12. PREPARATION, STARTUP AND CLEANUP TIMES PER MILKING
Single Operator Parlors, Washington, 1979

Herringbone Parlor	Preparation	Startup	Cleanup	Total
		Minutes		
Double 4	15	5	30	50
Double 6	15	5	30	50
Double 8	15	5	35	55
Double 10	15	5	35	55
12 Stall Trigon	15	5	35	55
16 Stall Polygon	15	5	40	60

The average preparation, startup and cleanup times contained in Table 12 can be combined with steady state throughput figures to approximate actual milking times. A recent analysis by Kelso of parlor downtime per milking, reflecting such factors as lunch breaks and holding area changes, indicates that an average of 10 minutes per 100 cows is a fairly accurate representation of experience for operators of herringbone parlors. Using this combination of information about times required for different operations, expected milking time for a herringbone double 4 parlor with no mechanization for a herd of 100 cows can be calculated as follows:

Generalized equation:

$$\begin{bmatrix}\text{Hours of} \\ \text{milking} \\ \text{time}\end{bmatrix} = \begin{bmatrix}\text{Preparation} \\ \text{+ startup} \\ \text{+ cleanup} \\ \text{times}\end{bmatrix} + \begin{bmatrix}\text{Steady state} \\ \text{milking time}\end{bmatrix} + \begin{bmatrix}\text{Parlor downtime}\end{bmatrix}$$

$$= \begin{bmatrix}\text{Preparation} \\ \text{+ startup} \\ \text{+ cleanup} \\ \text{times}\end{bmatrix} + \begin{bmatrix}\dfrac{\text{Herd size}}{\text{Steady state throughput}}\end{bmatrix} + \begin{bmatrix}(\text{Herd size}) \dfrac{\text{Downtime}}{\text{cow}}\end{bmatrix}$$

Herringbone double 4 time components

Preparation time: 15 minutes ($\frac{1}{4}$ hour)

Startup time: 5 minutes ($\frac{1}{12}$ hour)

Cleanup time: 30 minutes ($\frac{1}{2}$ hour)

Steady state throughput range: 33-44 cows per hour

Downtime: 10 minutes per 100 cows ($\frac{1}{600}$ hour per cow)

Hours of milking time for 100 cows

$$\text{Fast milking time} = \left(\frac{1}{4} + \frac{1}{12} + \frac{1}{2}\right) + \left(\frac{100}{44}\right) + \left(\frac{100}{600}\right)$$

$$= \left(\frac{5}{6}\right) + \left(\frac{100}{44} + \frac{100}{600}\right)$$

$$= \left(\frac{5}{6}\right) + 100\left(\frac{1}{44} + \frac{1}{600}\right)$$

$$= (0.833) + 100\ (0.0244)$$

$$= \underline{\underline{3.27 \text{ hours}}}$$

$$\text{Slow milking time} = \left(\frac{1}{4} + \frac{1}{12} + \frac{1}{2}\right) + \left(\frac{100}{34}\right) + \left(\frac{100}{600}\right)$$

$$= \left(\frac{5}{6}\right) + \left(\frac{100}{34} + \frac{100}{600}\right)$$

$$= \left(\frac{5}{6}\right) + 100\left(\frac{1}{34} + \frac{1}{600}\right)$$

$$= (0.833) + 100\ (0.0311)$$

$$= \underline{\underline{3.94 \text{ hours}}}$$

The fractional component of each hourly milking time estimate can be converted to minutes by multiplying it by 60. The above approach was used to derive general milking time equations for each of the milking systems evaluated. These equations are presented in Table 13. These generalized equations were subsequently used to estimate milking times for a number of different herd sizes. They were also used to estimate operating costs, which are determined in part by the time required to milk a herd of a given size.

Table 13. ESTIMATED MILKING TIME FOR SELECTED SYSTEMS
Single Operator Parlors, Washington State, 1979

System	Steady state Throughput Cows per hour		Preparation and cleanup Minutes/Mlkg.	Milking time equation 1/ Hrs. per milking
Herringbone, D-4	Fast	44	50	.833 + .0244 (herd size)
No mechanization	Avg.	39	50	.833 + .0272 (herd size)
	Slow	34	50	.833 + .0311 (herd size)
Herringbone, D-6	Fast	59	50	.833 + .0186 (herd size)
Detachers only	Avg.	50	50	.833 + .0217 (herd size)
	Slow	40	50	.833 + .0267 (herd size)
Herringbone, D-6	Fast	60	50	.833 + .0183 (herd size)
Detachers, power gates	Avg.	51	50	.833 + .0213 (herd size)
	Slow	42	50	.833 + .0255 (herd size)
Herringbone, D-6	Fast	62	50	.833 + .0178 (herd size)
Detachers, power gates,	Avg.	53	50	.833 + .0205 (herd size)
feedbowl covers	Slow	45	50	.833 + .0239 (herd size)
Herringbone, D-8	Fast	76	55	.917 + .0148 (herd size)
Detachers, power gates,	Avg.	63	55	.917 + .0175 (herd size)
feedbowl covers	Slow	49	55	.917 + .0221 (herd size)
Herringbone, D-10	Fast	82	55	.917 + .0139 (herd size)
Detachers, power gates,	Avg.	68	55	.917 + .0164 (herd size)
feedbowl covers	Slow	53	55	.917 + .0205 (herd size)
Trigon, 12 stall	Fast	74	55	.917 + .0152 (herd size)
Detachers, power gates,	Avg.	65	55	.917 + .0171 (herd size)
feedbowl covers	Slow	55	55	.917 + .0198 (herd size)
Polygon, 16 stall	Fast	85	60	1.000 + .0134 (herd size)
Detachers, power gates,	Avg.	76	60	1.000 + .0148 (herd size)
feedbowl covers	Slow	66	60	1.000 + .0168 (herd size)

1/ Equation to calculate hours per milking to prepare for milking, cleanup, and milk cows including 10 minutes of downtime per 100 cows to cover coffee breaks, problems, etc. For example, an estimate for 150 cows in a D-6 Herringbone with detachers only is .833 + .0217 (150) = 4.088 hrs. or 4 hours and 5 minutes.

Investment in Parlor and Equipment

Estimates of capital requirements for individual parlors were developed by asking contractors to bid on carefully specified plans for different parlors. This capital cost survey was taken in Whatcom and Skagit Counties in late 1978 and 1979. The data for a double 4 herringbone parlor are presented in Table 14, as an example of the procedures followed and the types of specific information collected.

Table 14. ESTIMATED CAPITAL COSTS, HERRINGBONE DOUBLE 4 PARLOR
Washington, 1979

Component	Number of Estimates	Mean of Estimates	3/4 Quartile Deviation	Cost Range
Parlor and holding pen construction	4	$18,100	$1,700	$16,400-19,800
Parlor painting	2	1,500	0	1,500
Plumbing-heating-electrical	3	3,900	200	3,700- 4,100
Parlor equipment	5	9,300	800	8,500-10,100
Milking equipment	4	11,700	1,100	10,600-12,800
Complete unmechanized parlor		44,500	3,850	40,650-48,350
Mechanization:				
Economy automatic detachers	4	1,900	150	1,750- 2,050
Deluxe automatic detachers	4	8,600	300	8,300- 8,900
Power gates	4	2,100	100	2,000- 2,200
Feedbowl covers	3	1,300	200	1,100- 1,500
Stimulating sprays	2	1,800	50	1,750- 1,850
Crowd gate	5	4,600	1,200	3,400- 5,800

The survey included only items which are likely to differ among alternative systems for a given herd size. Such items as bulk tanks were excluded. While the mean represents a central tendency around which cost estimates will tend to cluster, it provides no indication of the degree of variation found in actual construction. The measure of variation chosen to construct a range of probable costs is the quartile deviation. It is obtained by dividing the difference between the highest and lowest estimates by 4. For example, the estimates received for the construction of a herringbone, double 4 parlor with a 50 foot holding pen were as follows: $22,660, $19,052, $17,053, $13,541. The average of these is $\frac{\$72,306}{4} = \$18,076.50$, which is rounded to the nearest $100 or $18,100 to represent the mean. The quartile diviation is $\frac{\$22,660-\$13,541}{4}$ or $2,280. By adding and subtracting the quartile deviation from the mean a range can be constructed which includes exactly 50 percent of the difference between the highest and lowest estimates. In the example this range is equal to $18,100 ± $2,280 or a range of $15,820 to $20,380. Comparison of this range with the individual estimates shows that it includes two out of four. Since estimates will tend to cluster around the mean it is safe to assume that a one quartile range about the mean will contain over 50 percent of expected cost estimates. For this reason an arbitrary factor of 3/4 was chosen to adjust the quartile deviations to a smaller size. Roughly 50 percent of the expected cost estimates should fall within a range of 3/4 of a quartile deviation about the mean. The following example shows how the range was constructed:

$2,280 x 0.75 = $1,710

$1,710 rounded to the nearest $50 = $1,700

$18,100 ± $1,700 = a range of $16,400 to $19,800

The range in cost of a particular milking system component indicates to some extent the degree of savings that a dairyman might be able to achieve by shopping around and getting more estimates before agreeing to a contract. An easy way to calculate this variability is to divide the 3/4 quartile deviation into the mean of estimates and compare this percentage among components. Calculation of these percentages for two components in a herringbone double 4 indicated that crowd gates, with a cost variation ratio of $\frac{\$1,200}{\$4,600} = 26$ percent, deserved more attention before purchase than did deluxe automatic detachers, which had a cost variation ratio of $\frac{\$300}{\$8,600} = 3.5$ percent.*

Differential fixed costs for the basic parlor unit and mechanization options were calculated on the basis of a fifteen year planning horizon. Straight line depreciation was assumed. Conversations with tax assessors in Whatcom, Skagit and Snohomish Counties suggested that $15/thousand was an average annual real property tax rate. Communication with insurance companies indicated an average annual insurance rate of $6.50/thousand. The repair costs, replacement rates and salvage values in Table 15 were based on estimates developed at Washington State University. Buildings included construction, parlor painting and plumbing-heating-electrical costs as well.

Table 15. ESTIMATED SALVAGE VALUES, ANNUAL REPAIR COSTS AND REPLACEMENT RATES Milking System Components, Washington, 1979

Component	Salvage value	Annual repair costs
	percent of outlay	
Buildings	10	4
Parlor equipment		
Replace at 10 years	10	4
15th year	55	4
Milking equipment		
Replace at 7.5 years	10	6
Mechanization		
Replace at 5 years	0	8

Source: Willett.

An after-tax discount rate of 10 percent was used to calculate discounted cash flows over a 15 year period as a means of estimating fixed costs associated with these capital outlays. This rate is based on an average three to five

* One should not assume that very small variation in prices of automatic detachers will occur in all regions on the basis of these limited observations.

year loan rate of 12 percent commonly used to finance new parlors, quoted by Peoples State Bank, Lynden, Washington. Most dairymen are faced with marginal federal income tax brackets. A rate of 24 percent is used in this study. Multiplied together, these two figures give an after-tax rate of 9.12 percent which is rounded up to 10 percent to allow for the possibility that an average dairyman's equity cost of capital is higher than his debt cost of capital. Investment tax credits equal to 10 percent of the initial outlays for buildings, parlor equipment and milking equipment were assumed. Similar credits amounting to 6 2/3 percent of mechanization outlays were also used.

The use of a constant marginal federal income tax rate of 24 percent is an oversimplification which can be made only for a generalized study. The 24 percent rate has been chosen with the assumption that individual dairymen's marginal tax rates will be to some degree normally distributed around the 24 percent bracket. Another facet of this simplification is the failure to acknowledge that the cost savings realized as a result of proper milking system selection may move a dairyman into a higher tax bracket. This condition reduces the amount of after-tax savings attained by choosing a more efficient system.

Table 16. SUMMARY OF 15 YEAR DISCOUNTED BUILDING OUTLAYS
Herringbone Double 4 Parlor, Washington, 1979

Year	Outlay	Amount before tax	Amount after tax	10% factor	Present value
0	Outlay	$23,500	$23,500	1.0	$23,500
1-15	Repairs-insurance-taxes	1,445	1,098	7.6061	8,351
1	Investment tax credit		-2,350	0.9091	-2,136
1-15	Depreciation tax savings		-338	7.6061	-2,571
15	Salvage value		-2,350	0.2394	-563
0	Total 15 year discounted building outlays				$26,581

Table 17. SUMMARY OF 15 YEAR DISCOUNTED PARLOR EQUIPMENT OUTLAYS
Herringbone Double 4 Parlor, Washington, 1979

Year	Outlay	Amount before tax	Amount after tax	10% factor	Present value
0	Outlay	$9,300	$9,300	1.0	$9,300
10	Outlay	9,300	9,300	0.3855	3,585
1-15	Repairs-insurance-taxes	572	435	7.6061	3,309
1	Investment tax credit		-930	0.9091	-845
11	Investment tax credit		-930	0.3505	-326
1-15	Depreciation tax savings		-201	7.6061	-1,529
10	Salvage value		-930	0.3855	-359
15	Salvage value		-5,115	0.2394	-1,225
0	Total 15 year discounted parlor equipment outlays				$11,910

Table 18. SUMMARY OF 15 YEAR DISCOUNTED STANDARD MILKING EQUIPMENT OUTLAYS
Herringbone Double 4 Parlor, Washington, 1979

Year	Outlay	Amount before tax	Amount after tax	10% factor	Present value
0	Outlay	$11,700	$11,700	1.0	$11,700
7.5	Outlay	11,700	11,700	0.4893	5,725
1-15	Repairs-insurance-taxes	954	725	7.6061	5,514
1	Investment tax credit		-1,170	0.9091	-1,064
8	Investment tax credit		-1,170	0.4665	-546
1-15	Depreciation tax savings		-337	7.6061	-2,563
7.5	Salvage value		-1,170	0.4893	-573
15	Salvage value		-1,170	0.2394	-280
0	Total 15 year discounted milking equipment outlays				$17,911

A discounted differential cash flow summary for each of the three base components -- buildings, parlor equipment and standard milking equipment for a herringbone double 4 parlor is shown in Tables 16-18. Presented in Table 19 is a summary for automatic detachers in a double 6 herringbone parlor.

Table 19. SUMMARY OF 15 YEAR AUTOMATIC DETACHER EXPENSES
Herringbone Double 6 Parlor, Washington, 1979

Year	Outlay	Amount before tax	Amount after tax 1/	10% factor	Present value
0	Outlay	$12,500	$12,500	1.0	$12,500
5	Outlay	12,500	12,500	0.6209	7,761
10	Outlay	12,500	12,500	0.3855	4,819
1-15	Repairs-insurance-taxes	1,269	964	7.6061	7,332
1	Investment tax credit		-834	0.9091	-758
6	Investment tax credit		-834	0.5645	-471
11	Investment tax credit		-834	0.3505	-292
1-15	Depreciation tax savings		-600	7.6061	-4,564
	Present value of automatic detacher expenses				$26,327

1/ Assumes 24 percent marginal tax rate.

A less complex approach to the calculation of fixed costs is the traditional "average annual cost" method. This technique differs from discounted cash flow approaches in two ways: it allocates a specific amount of capital depreciation to each year and it charges interest on the average capital investment. The discounted cash flow approach eliminates the need for yearly capital amortization by evaluating the entire investment at one point in time. Allowance for interest on investment is made by reducing the size of future cash flows using a discount rate.

A useful concept in the comparison of discounted cash flows and average annual costs is the annual equivalent cash flow. This factor is established by dividing discounted cash flow estimates by the factor which adjusts equal annual cash flows to present value terms. In this manner, the annual equivalent cash flow represents the average cash flow over the length of the period under consideration, which has a present value equal to the discounted cash flow estimate.

An example illustrates the use of annual equivalent cash flows, while highlighting the differences between discounted cash flows and annual costs. The 15 year discounted building expenses for a double 4 herringbone parlor are estimated at \$26,581 (Table 16). A factor of 7.6061 adjusts 15 annual cash flows to present value terms at a discount rate of 10 percent. Dividing this factor into \$26,581 furnishes an annual equivalent cash flow of $\frac{\$26{,}581}{7.6061} = \$3{,}495$. This figure may then be compared to the annual building costs estimated in Table 20. Investment credit is included in the annual cost analysis by subtracting it from the initial outlay figure used to calculate depreciation and interest.

Table 20. ANNUAL AVERAGE BUILDING EXPENSES
Herringbone Double 4 Parlor, Washington, December 1978

Item	Method of calculation	Annual average expense
Depreciation	$\frac{21{,}150 - 2{,}350}{15}$	\$1,253
Interest	$\frac{21{,}150 + 2{,}350}{2} \times 10\% =$	1,175
Repairs-insurance-taxes	$23{,}500 \times 6.15\% \times 0.8 =$	1,156
Depreciation tax savings	$\frac{23{,}500 - 2{,}350}{15} \times 0.24 =$	-338
Total annual building expenses		\$3,246

Comparison of the annual average cost figure (\$3,246) with the annual equivalent cash flow (\$3,495) suggests that the annual average cost approach tends to understate the actual magnitude of fixed costs. Interest on investment is the source of most of the difference in the two cost estimates. By charging interest only on average investment over the time span selected the annual average cost approach assesses parlors with high fixed costs in a more favorable light than does the discounted cash flow method. This is an important reason for using discounted cash flows rather than annual average costs.

Each of the expenses associated with the four components in Tables 16-19 is directly proportional to the amount of the initial outlay. Therefore, total outlays can be expressed as a constant percentage of the original cost of each component. This condition allows for the use of a discounted cash flow (DCF) expansion factor to relate initial outlays to 15 year discounted cash flows. Because this factor is constant for all initial outlays it eliminates the need to calculate complete fixed costs summaries for each milking system alternative.

The factors calculated from Tables 16-19 are:

Buildings: $\frac{26,581}{23,500} = 1.1311$

Parlor equipment: $\frac{11,910}{9,300} = 1.2806$

Milking equipment: $\frac{17,911}{11,700} = 1.5309$

Mechanization: $\frac{26,327}{12,500} = 2.1062$

Total fixed costs discounted over 15 years were estimated by multiplying the initial outlay for a given component in any parlor by the appropriate DCF expansion factor. For example, initial milking equipment investment in a 12 stall trigon was $16,000 as given in Table 31 in Appendix B. Multiplying this outlay figure by the DCF milking equipment expansion factor of 1.5309 showed that $24,494 was the estimated present value of all fixed expenses related to trigon milking equipment over a 15 year period. The same procedure was used to calculate 15 year discounted cash flows associated with differential fixed costs for each milking system. These results are summarized in Tables 21 and 22.

Table 21. SUMMARY OF 15 YEAR DISCOUNTED FIXED COSTS
8 or 12 Stall Milking Systems, Washington, 1979

Milking System	Component	Initial outlay	DCF expansion factor	Present value of 15 years fixed costs
Herringbone	Buildings	$23,500	1.1311	$26,581
Double 4	Parlor equipment	9,300	1.2806	11,910
No mechanization	Milking equipment	11,700	1.5309	17,912
	Total			56,403
Herringbone	Buildings	28,400	1.1311	32,123
Double 6	Parlor equipment	11,700	1.2806	14,983
Automatic detachers	Milking equipment	15,100	1.5309	23,117
	Mechanization	12,500	2.1062	26,328
	Total			96,551
Herringbone	Buildings	28,400	1.1311	32,123
Double 6	Parlor equipment	11,700	1.2806	14,983
Automatic detachers	Milking equipment	15,100	1.5309	23,117
Power gates	Mechanization	14,600	2.1062	30,751
	Total			100,974
Herringbone	Buildings	28,400	1.1311	32,123
Double 6	Parlor equipment	11,700	1.2806	14,983
Automatic detachers	Milking equipment	15,100	1.5309	23,117
Power gates	Mechanization	16,200	2.1062	34,120
Feedbowl covers	Total			104,343
12 stall	Buildings	40,800	1.1311	46,149
Trigon	Parlor equipment	15,000	1.2806	19,209
Automatic detachers	Milking equipment	16,000	1.5309	24,494
Power gates	Mechanization	17,500	2.1062	36,859
	Total			126,711

Table 22. SUMMARY OF 15 YEAR DISCOUNTED FIXED COSTS
16 and 20 Stall Milking Systems, Washington, 1979

Milking System	Component	Initial outlay	DCF expansion factor	Present value of 15 years fixed costs
Herringbone	Buildings	$33,600	1.1311	$38,005
Double 8	Parlor equipment	14,600	1.2806	18,697
Automatic detachers	Milking equipment	18,500	1.5309	28,322
Power gates	Mechanization	20,800	2.1062	43,809
Feedbowl covers	Total			128,833
Herringbone	Buildings	37,700	1.1311	42,642
Double 10	Parlor equipment	17,200	1.2806	22,026
Automatic detachers	Milking equipment	23,100	1.5309	35,364
Power gates	Mechanization	24,600	2.1062	51,813
Feedbowl covers	Total			151,845
16 stall	Buildings	54,400	1.1311	61,532
Polygon	Parlor equipment	19,800	1.2806	25,356
Automatic detachers	Milking equipment	22,400	1.5309	34,292
Power gates	Mechanization	23,700	2.1062	49,917
	Total			171,097

Operating Costs

Labor dwarfs all other types of costs in operating a milking parlor. This is one of the primary reasons for looking carefully at throughput figures in evaluating different milking systems. Three specific categories of operating costs were considered in this analysis: labor, electricity consumption and gas heating costs. Each of these costs was estimated on an hourly basis. The number of hours required per milking shift was then multiplied by 730 to obtain annual operating costs. When a typical marginal tax rate of 24 percent was assumed, before-tax cash flows were adjusted to after-tax cash flows by multiplying the before-tax flows by a factor of 0.76.

Water - Costs associated with water use in milking systems include purchase price or other costs of acquisition of the source of supply (such as well-drilling and maintenance costs), costs of disposal and costs due to heating water for stimulation and cleaning. Costs related to acquisition and disposal are likely to be more closely related to herd size than parlor size and have been omitted from this analysis. While the amount of hot water used for cleanup is related to parlor size, the use of warm water for stimulation is directly proportional to the number of lactating cows. Water heating costs have also been left out as an item of operating costs for the parlor in light of the increasing acceptance of heat exchange systems enabling dairymen to use heat from the milk obtained in the parlor to heat water for stimulation and cleanup. In some cases these systems have eliminated the operating costs of hot water tanks altogether. Costs associated with cooling and storing milk have also been ignored because they are separable and strongly related to herd and bulk tank size. Only those operating costs associated with differences in the milking systems themselves were included.

Labor - The assignment of a value to each hour of labor needed for parlor operation is both important and difficult. If milking labor is hired, the cost to the dairyman includes fringe benefits and employment taxes in addition to the hourly wage rate. If the dairyman uses family labor, the value of labor must reflect opportunity costs, which are bound to differ throughout the year as time demands of cropping and other seasonal activities differ. Also, opportunity costs will increase as the time demands of milking increase: a longer milking shift reduces the time a dairyman has available at his discretion with less time available for management and supervision.

For this analysis labor was valued at \$6 per hour of milking, the average wage paid to relief milkers in Whatcom County. A study by Willett which also included fringe benefits and employment taxes yielded similar results for fulltime milkers in King County. Labor paid at \$6 per milking hour multiplied by 730 milkers results in a before-tax annual cost of \$4,380 per hour of milking. Adjusting for income tax savings associated with labor cost deductions yields an after-tax annual cost per hour of milking of \$3,329.

Electricity - Electricity consumption in the milking operation was assumed to be directly related to the horsepower rating of the motor on the vacuum pump and the length of the milking shift. No other electrical costs attributable to additional mechanization were included in the budgets. Conversations with milking equipment personnel indicated that not all automatic detachers require electricity: some can run off the vacuum supplied by the vacuum pump. Power gates and feedbowl covers almost always are powered by vacuum.

Consumption figures of 0.9 KwH per horsepower per hour of milking was assumed for the operation of a vacuum pump. Washington electricity rates have fallen between 1¢ and 3¢ per kilowatt hour. The highest rate is used to illustrate how annual electricity costs were established for a double 4 herringbone parlor:

Horsepower rating of vacuum pump motor = 7.5 HP

7.5 HP x 0.9 KwH/HP/hour = 6.75 KwH/hour of milking

6.75 KwH/hour x \$0.03/KwH = \$0.2025/hour of milking

\$0.2025/hour of milking x 730 hours of milking/annual hour of milking

= \$147.825/annual hour of milking, before tax

\$147.825/annual hour of milking, before tax x 0.76 after-tax adjustment

= \$112.35/annual hour of milking

Heat - Gas heating costs appear to be correlated most consistently with total stall length in any particular parlor. An annual rate of 30¢ per foot of space per hour of milking was used to approximate gas heating costs for a herringbone double 4 parlor:

Total stall length of parlor = 37.5 feet

37.5 feet x $0.30/foot/annual hour of milking

= $11.25/annual hour of milking, before tax

$11.25/annual hour of milking, before tax x 0.76 after-tax adjustment

= $8.55/annual hour of milking

Adding together the three variable cost components of labor, electricity and gas heating produces the estimates of annual, after-tax operating costs are presented in Table 23.

Table 23. ANNUAL AFTER-TAX, OPERATING COSTS PER HOUR OF MILKING TIME
6 Selected Milking Parlors, Washington, 1979

	Annual After-Tax Costs Per Hour of Milking Time				
Parlor	Labor	Electricity	Gas heating	Total operating	Labor as a percentage of total
Herringbone Double 4	$3,329	$112	$ 9	$3,450	97
Herringbone Double 6	3,329	150	11	3,490	95
12 Stall Trigon	3,329	150	14	3,493	95
Herringbone Double 8	3,329	225	14	3,568	93
16 Stall Trigon	3,329	225	20	3,574	93
Herringbone Double 10	3,329	299	17	3,645	91

Labor comprises the major portion of operating costs in all of the parlors, from 91 to 97 percent of the total. Electricity and gas heating costs could differ significantly from the assumed quantities used and rates charged without changing the relative relationships among individual parlors. Labor costs, on the other hand, are the significant component in operating costs. An increase in milking wages to $7 per hour would increase after-tax labor costs from $3,329 per hour of milking time to $3,884 per hour of milking time. A decrease to $5 per hour would reduce after-tax, annual wages to $2,774 per hour of milking time.

Annual after-tax operating costs for a herringbone double 4 parlor were estimated to be \$3,450 per hour of milking (Table 23). Multiplying this value by 7.6061, the factor which adjusts 15 yearly cash flows to present value terms at a 10 percent discount rate, yields \$26,241 per hour of milking time. Attaching this value to the fast and slow milking times found in Table 13 provides a set of upper and lower bounds, respectively, for a 15 year discounted set of operating costs for each system. For the herringbone double 4 parlor this set of operating costs was constructed in the following manner:

15 year discounted after-tax operating costs = \$26,241/hour

Fast milking (44 cows/hour) time in hours = 0.833 + 0.0244 (herd size)

Low operating costs = 0.833 + 0.0244 (herd size) x \$26,241

= <u>\$21,859 plus \$640 (herd size)</u>

Slow milking (34 cows/hour) time in hours = 0.833 + 0.0311 (herd size)

High operating costs = 0.833 + 0.0311 (herd size) x \$26,241

= <u>\$21,859 plus \$816 (herd size)</u>

The above method was used to derive the upper and lower bounds of a 15 year discounted operating cost range for each milking system. The results for each of the eight systems are presented in Table 24. Most dairymen should expect to find their own after-tax operating costs lying somewhere between the high and low points specified in Table 24. Good milking management should coincide with throughput rates at the upper end of the range. As throughput rates approach the top of the attainable range, operating costs will fall. The same relationship links slower throughputs to higher operating costs.

<u>Milking Costs Per Cow</u>

Adding together the 15 year discounted after tax operating and fixed costs, presented in Tables 21, 22 and 24 furnishes a total cost figure for milking in each system. When discounted over 15 years this total really represents the present value of all differential expenses incurred over a 15 year planning horizon. Some estimate of expected rates of inflation is not included in any of the operating cost estimates.

Cost ranges per cow can be obtained by dividing a specified herd size into the high and low total cost figures for each system considered. In a manner similar to the calculations made for operating costs, total milking costs after taxes consist of a constant component and a variable component related to herd size. The constant component of total milking costs incorporates the constant factor in operating costs as well as the entire fixed cost figure for a given milking system. The variable component of total milking costs is the same as the variable component of operating costs:

15 year discounted milking costs = Fixed cost + Operating costs

= Fixed costs + Constant component of operating costs + Variable operating costs times herd size

Table 24. RANGE OF 15 YEAR DISCOUNTED AFTER-TAX OPERATING COSTS
8 Selected Milking Systems, Washington, 1979

Milking System	Milking speed (Cows/Hour)	Range of 15 year discounted operating costs
Herringbone Double 4 None	Fast: 44	Low operating costs: $21,859 plus $640 (herd size)
	Slow: 34	High operating costs: $21,859 plus $816 (herd size)
Herringbone Double 6 Automatic detachers	Fast: 59	Low operating costs: $22,112 plus $494 (herd size)
	Slow: 40	High operating costs: $22,112 plus $709 (herd size)
Herringbone Double 6 Automatic detachers & power gates	Fast: 60	Low operating costs: $22,112 plus $486 (herd size)
	Slow: 42	High operating costs: $22,112 plus $677 (herd size)
Herringbone Double 6 Automatic detachers, power gates & feed-bowl covers	Fast: 62	Low operating costs: $22,112 plus $473 (herd size)
	Slow: 45	High operating costs: $22,112 plus $634 (herd size)
Herringbone Double 8 Automatic detachers, power gates & feed-bowl covers	Fast: 76	Low operating costs: $24,886 plus $402 (herd size)
	Slow: 49	High operating costs: $24,886 plus $600 (herd size)
Herringbone Double 10 Automatic detachers, power gates & feed-bowl covers	Fast: 82	Low operating costs: $25,423 plus $385 (herd size)
	Slow: 53	High operating costs: $25,423 plus $568 (herd size)
12 Stall Trigon Automatic detachers & power gates	Fast: 74	Low operating costs: $24,363 plus $404 (herd size)
	Slow: 55	High operating costs: $24,363 plus $526 (herd size)
16 Stall Polygon Automatic detachers & power gates	Fast: 85	Low operating costs: $27,184 plus $364 (herd size)
	Slow: 66	High operating costs: $27,184 plus $457 (herd size)

For the Herringbone, Double 4 Parlor with no mechanization, 15 year total discounted cost equal:

$$
\begin{aligned}
\text{Slow milking (34 cows/hour) costs} &= \text{Fixed costs + High operating costs} \\
&= \$56,403 + (\$21,859 + \$816)\ (\text{herd size}) \\
&= (\$56,403 + \$21,859) + \$816\ (\text{herd size}) \\
&= \$78,262 + \$816\ (\text{herd size})
\end{aligned}
$$

$$
\begin{aligned}
\text{Fast milking (44 cows/hour) costs} &= \text{Fixed costs + Low operating costs} \\
&= \$56,403 + (\$21,859 + \$640)\ (\text{herd size}) \\
&= (\$56,403 + \$21,859) + \$640\ (\text{herd size}) \\
&= \$78,262 + \$640\ (\text{herd size})
\end{aligned}
$$

Adjusting total costs to costs per cow merely entails dividing total costs by herd size:

$$\text{Slow milking (34 cows/hour) per-cow costs} = \frac{\$78,262}{\text{herd size}} + \$816$$

$$\text{Fast milking (44 cows/hour) per-cow costs} = \frac{\$78,262}{\text{herd size}} + \$640$$

For a herd of 50 cows the range of costs per cow is determined as follows:

$$\text{Slow milking (34 cows/hour) per-cow costs} = \frac{\$78,262}{50} + \$816 = \$2,381$$

$$\text{Fast milking (44 cows/hour) per-cow costs} = \frac{\$78,262}{50} + \$640 = \$2,205$$

Range of 15 year discounted milking costs per cow: $2,205 - $2,381

The difference in this range is always the difference between the two variable cost components, $816 and $640, or $176 in this case. While this range in cost at first glance seems fairly narrow it represents only differences for one cow over 15 years. When the full herd size is considered the difference is more substantial. For 50 cows over 15 years the range is from $110,262 to $119,062, a difference of $8,800.

These procedures were used to calculate total milking costs per cow for each system for herd sizes of 50 to 500 cows. The results are presented in Figures 1-8. Fifteen year discounted costs per cow for some of the slower systems were not estimated for the larger herds. In these cases that number of cows cannot be milked twice in a 24 hour period in that size parlor.

Cost ranges are a realistic and effective method of illustrating the nature of cost variation for individual milking systems but they are somewhat unwieldy for comparing two or more systems. Two very different systems, the herringbone double 4, which has the lowest fixed cost component and the highest variable cost component, and the 16 stall polygon, which has the highest fixed cost component and the lowest variable cost component, are somewhat competitive in terms of costs over a herd size range of 275 to 350 (Figure 9). The cross-hatching in the illustration shows where the cost ranges of the two systems overlap. The cost curves for the double 4 herringbone stop at a herd size of 350 because that system is not capable of milking any more cows twice in one day. The lower curve for double 4 (fast milking speed) could be extended to 450.

Figure 1. HERRINGBONE DOUBLE 4 PARLOR, NO MECHANIZATION
15 Year Discounted Milking Cost Per Cow by Herd Size
Washington, 1979

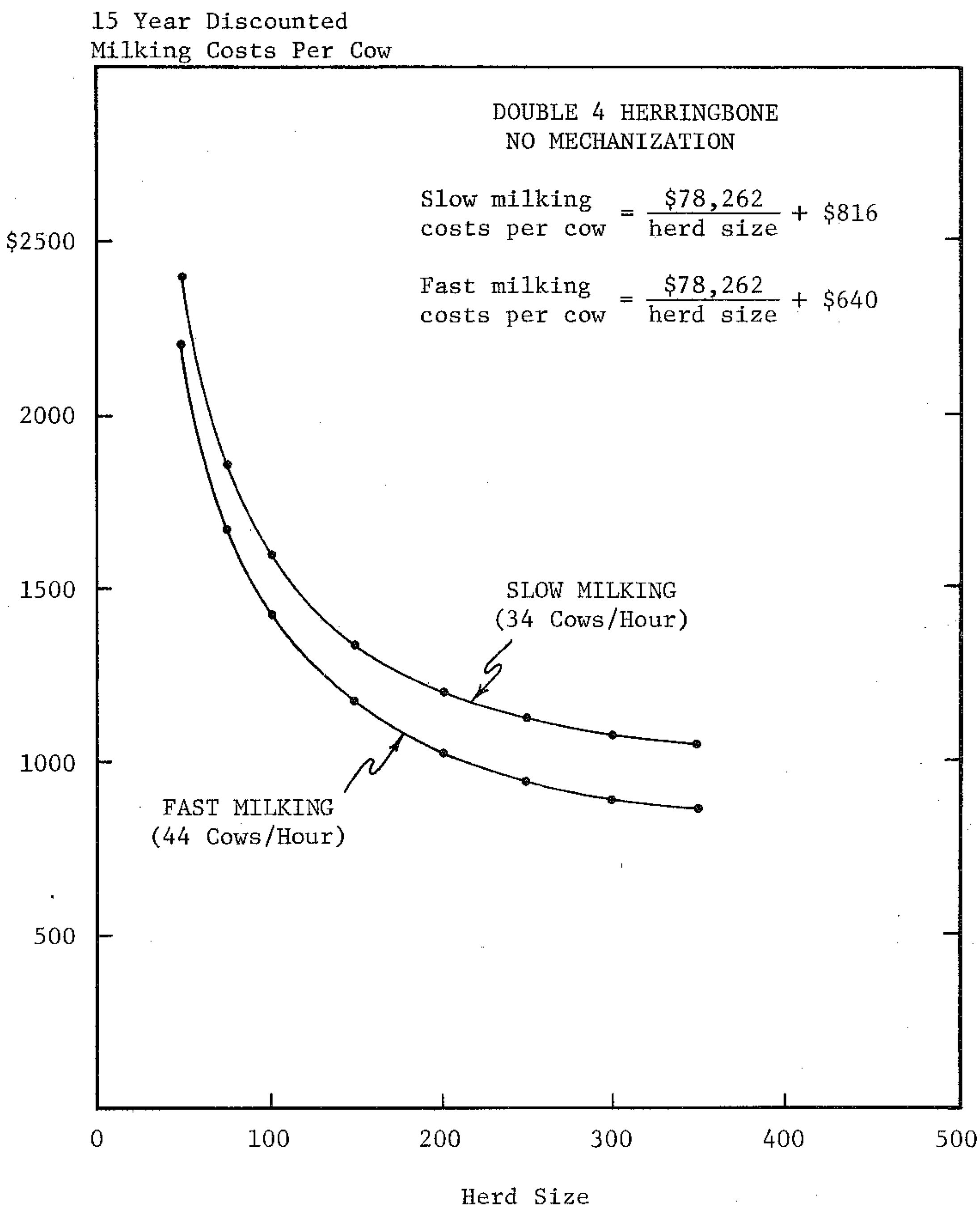


Figure 2. HERRINGBONE DOUBLE 6 PARLOR WITH AUTOMATIC DETACHERS
15 Year Discounted Milking Cost Per Cow by Herd Size
Washington, 1979

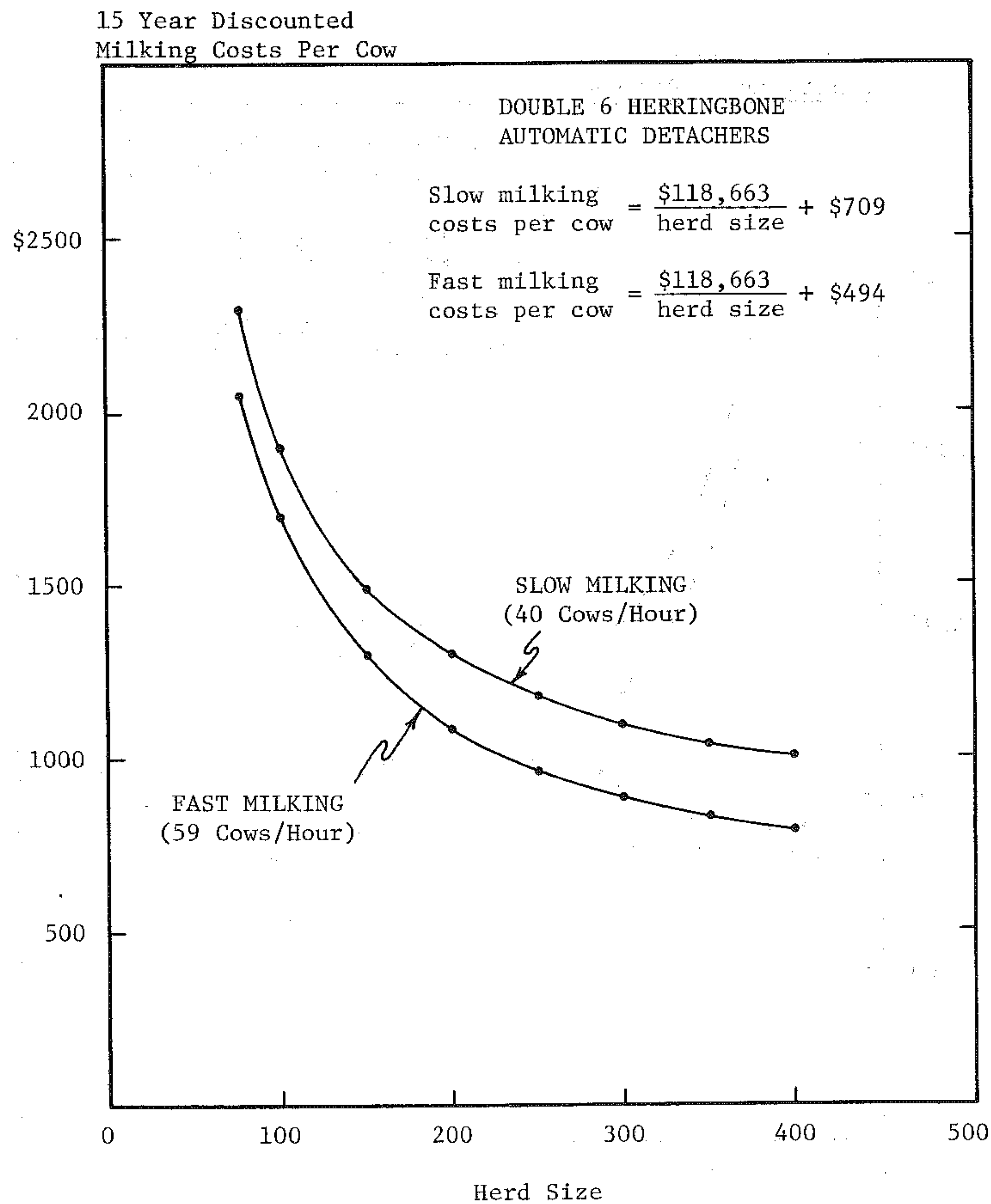


Figure 3. HERRINGBONE DOUBLE 6 PARLOR WITH AUTOMATIC DETACHERS AND POWER GATES
15 Year Discounted Milking Cost Per Cow by Herd Size
Washington, 1979

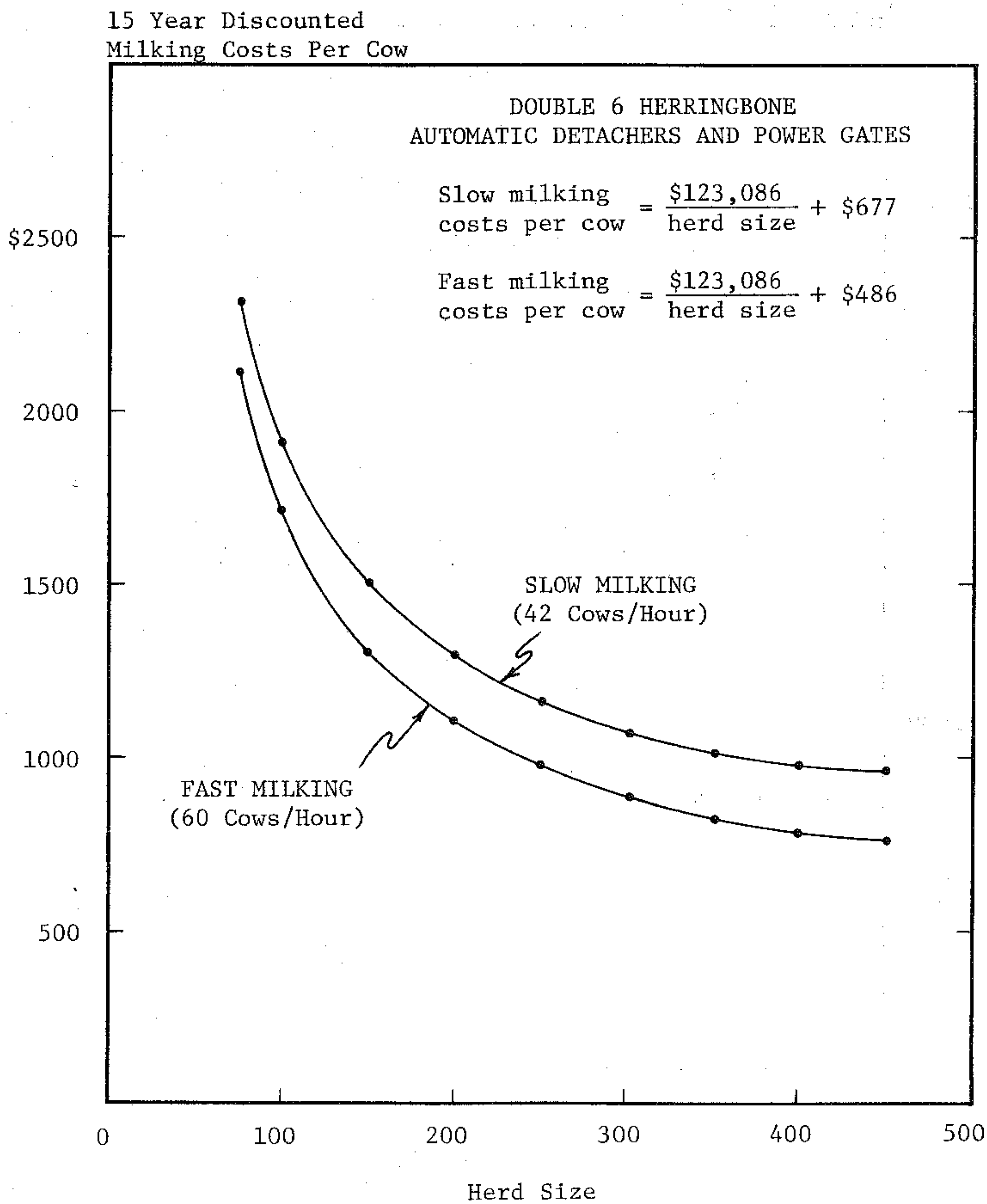


Figure 4. HERRINGBONE DOUBLE 6 PARLOR WITH AUTOMATIC DETACHERS, POWER GATES AND FEEDBOWL COVERS
15 Year Discounted Milking Cost Per Cow by Herd Size
Washington, 1979

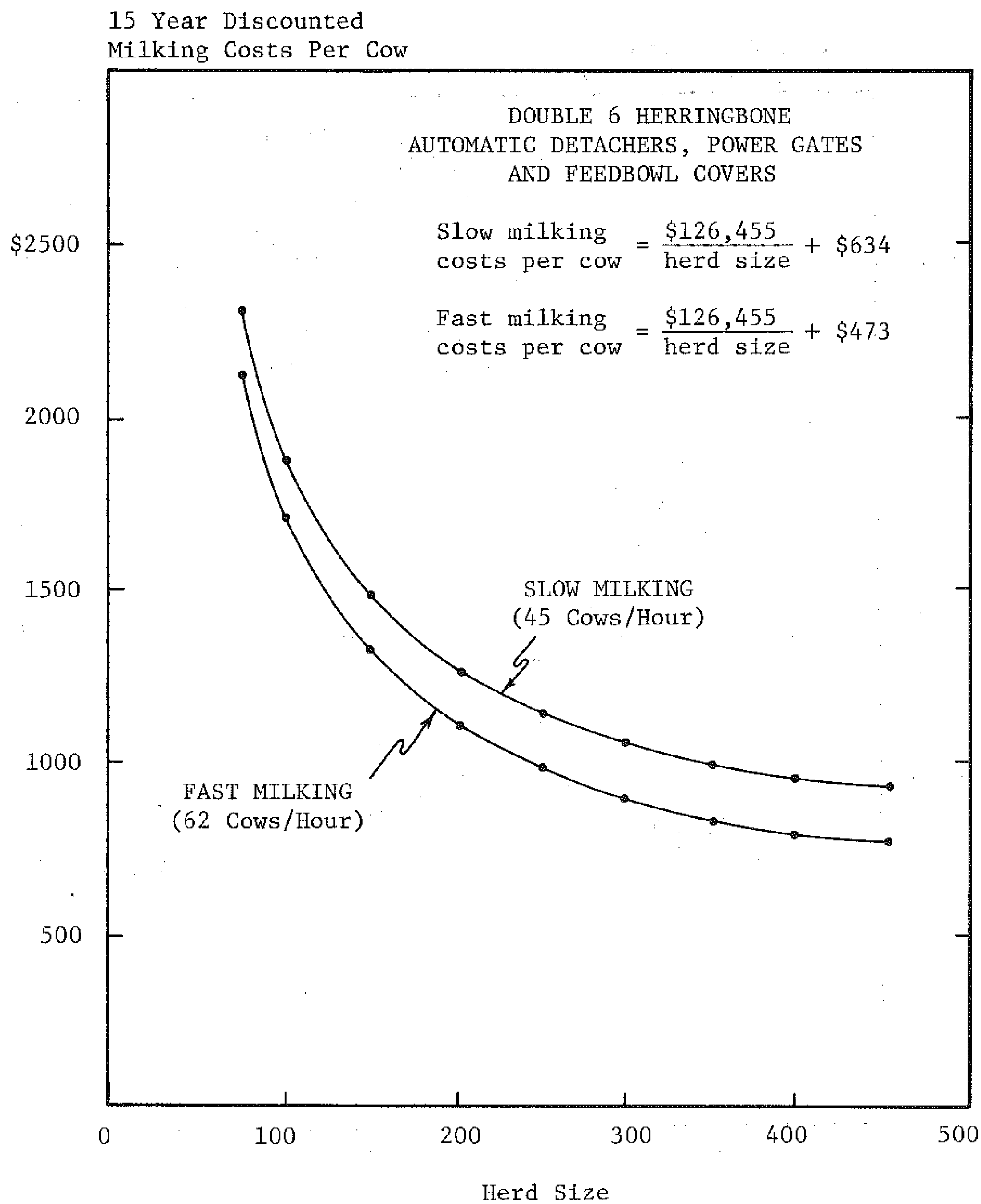


Figure 5. HERRINGBONE DOUBLE 8 PARLOR WITH AUTOMATIC DETACHERS, POWER GATES AND FEEDBOWL COVERS
15 Year Discounted Milking Cost Per Cow by Herd Size
Washington, 1979

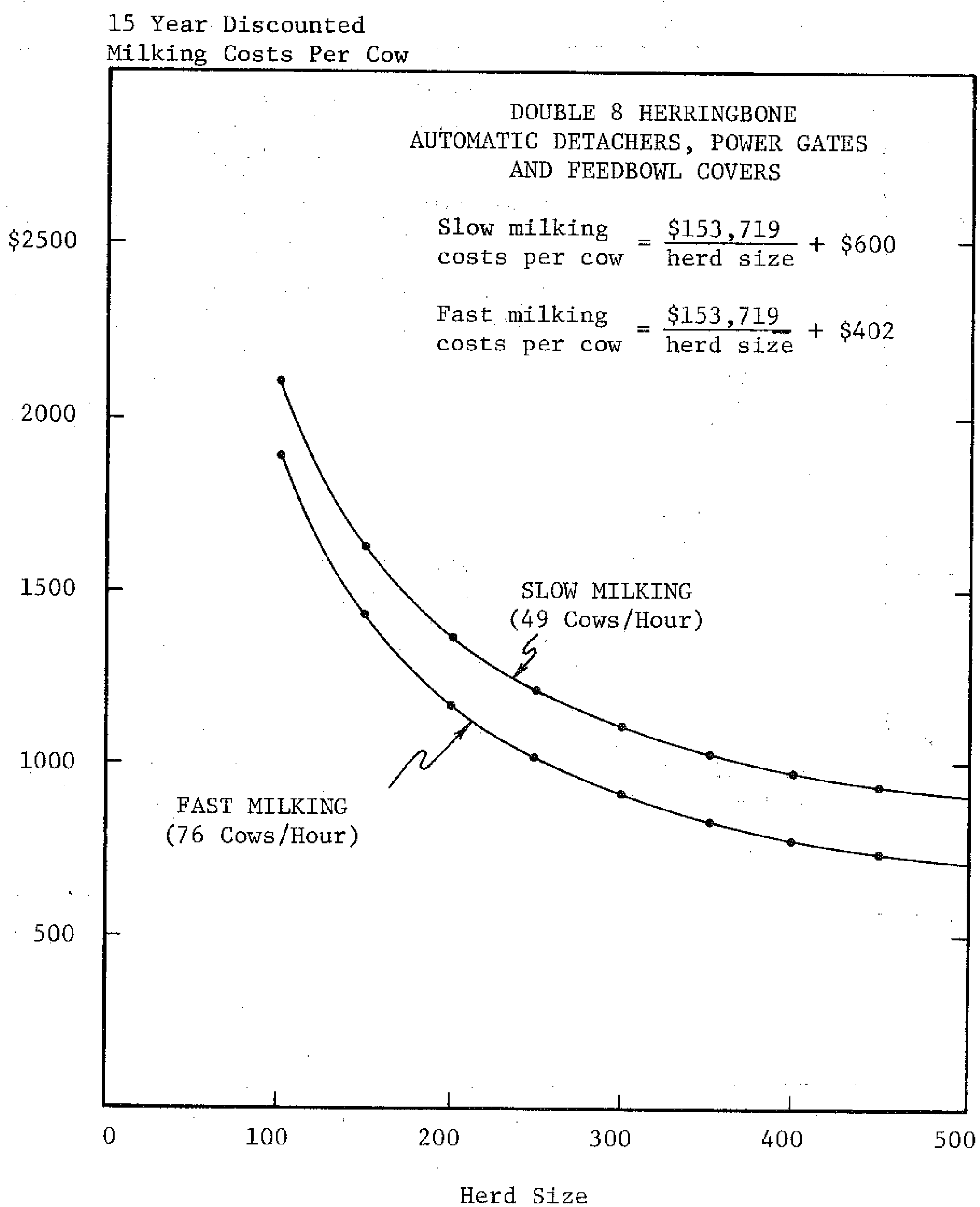


Figure 6. HERRINGBONE DOUBLE 10 PARLOR WITH AUTOMATIC DETACHERS, POWER GATES AND FEEDBOWL COVERS
15 Year Discounted Milking Cost Per Cow by Herd Size
Washington, 1979

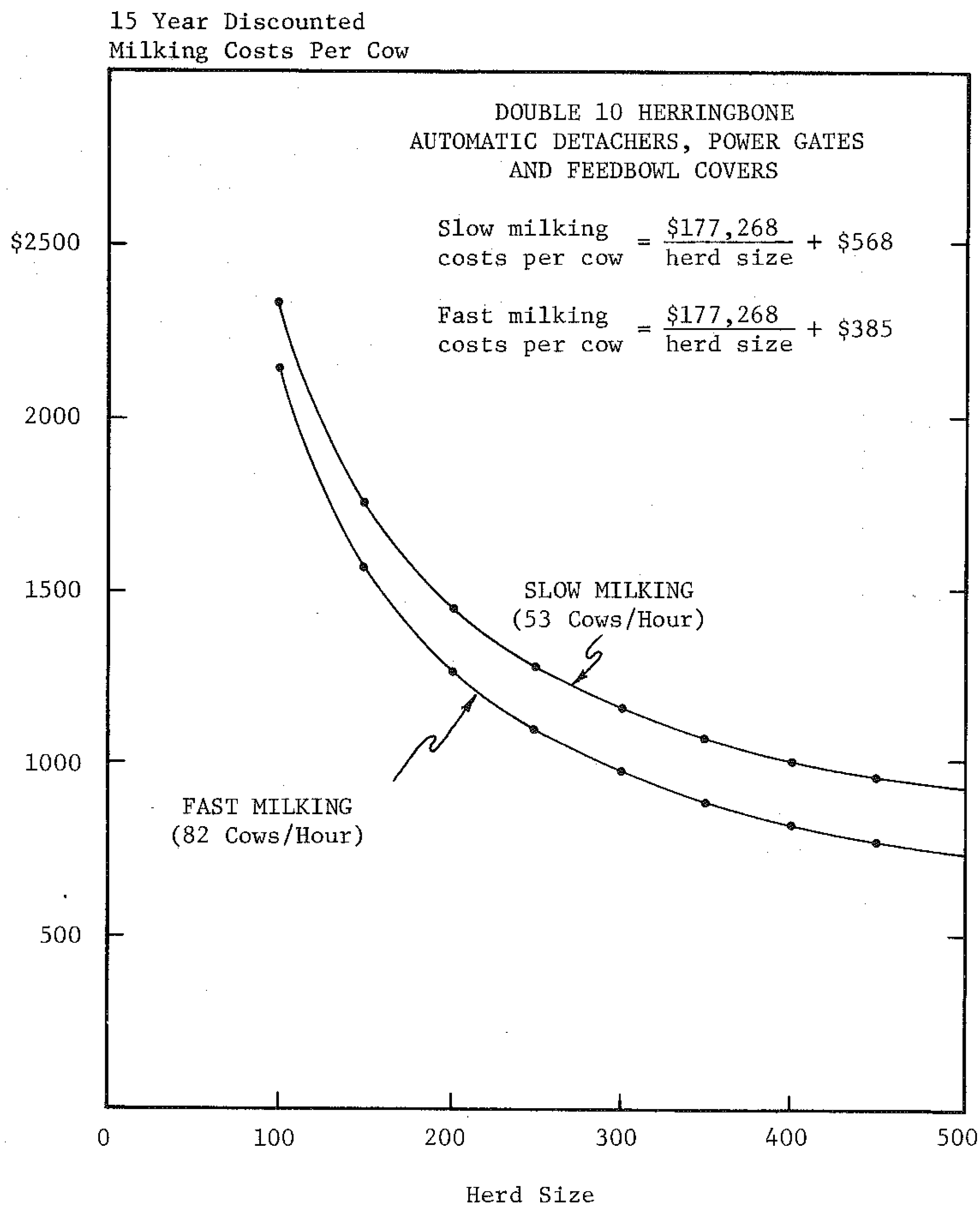


Figure 7. 12 STALL TRIGON PARLOR WITH AUTOMATIC DETACHERS AND POWER GATES
15 Year Discounted Milking Cost Per Cow by Herd Size
Washington, 1979

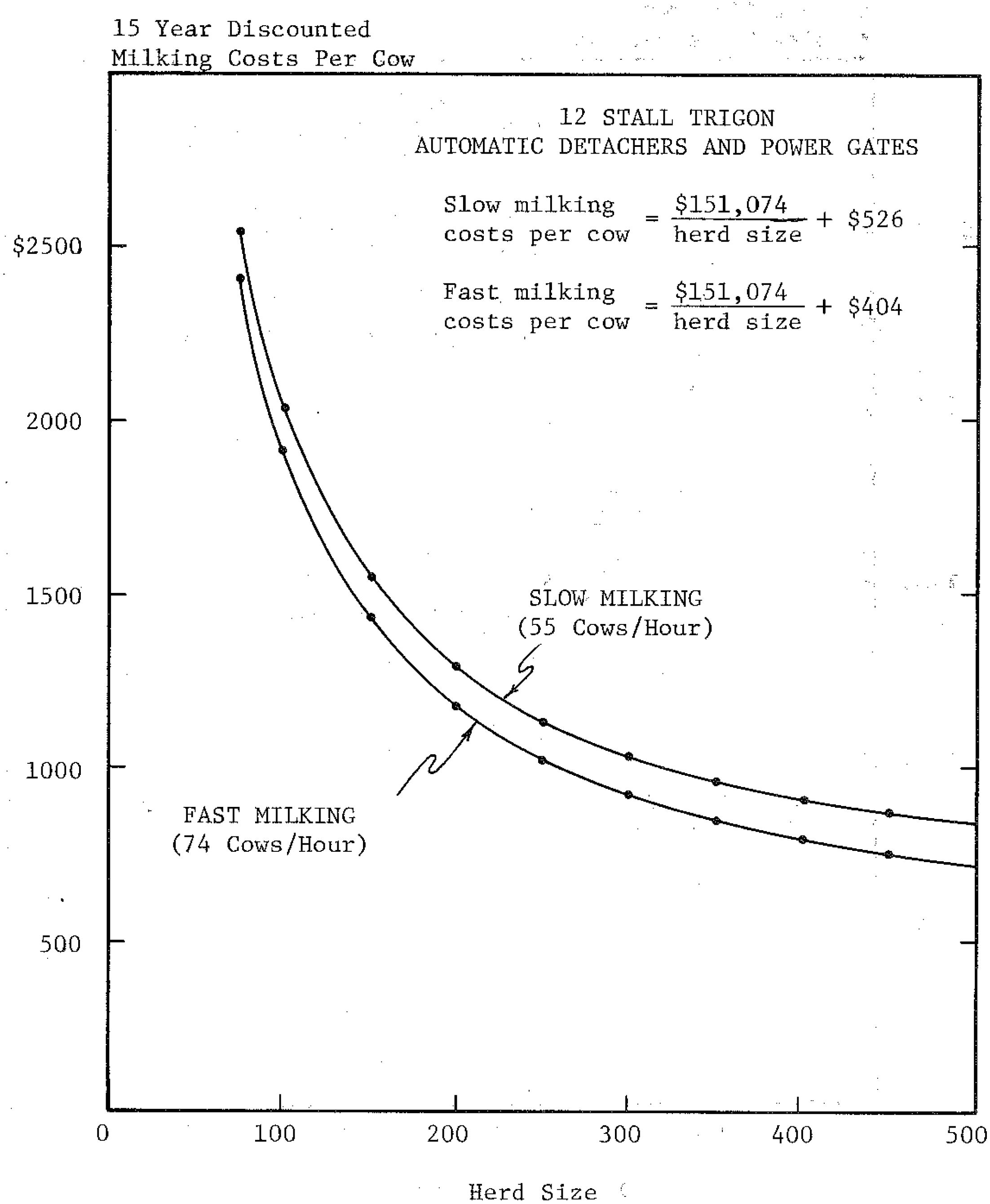


Figure 8. 16 STALL POLYGON PARLOR WITH AUTOMATIC DETACHERS AND POWER GATES
15 Year Discounted Milking Cost Per Cow by Herd Size
Washington, 1979

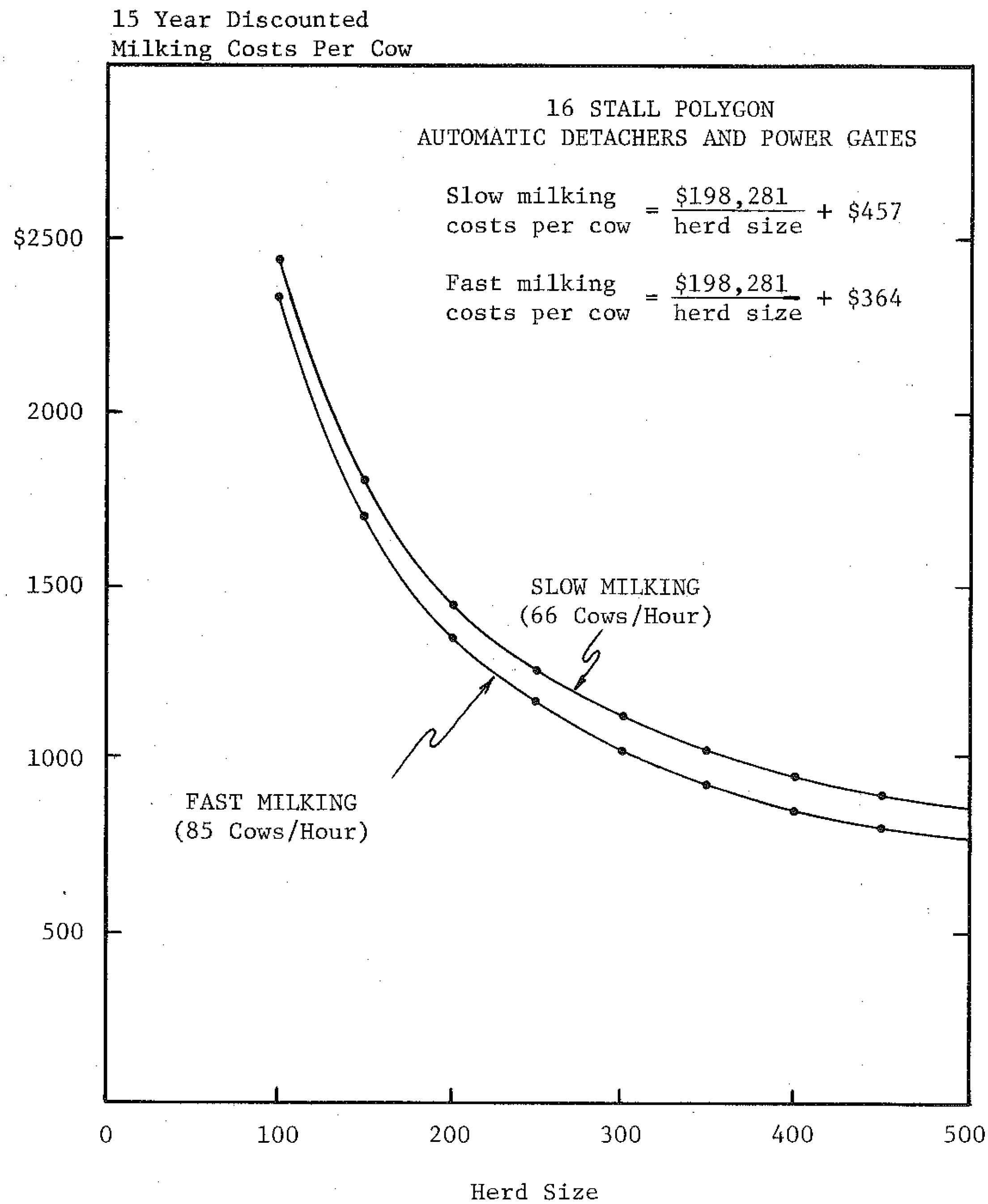
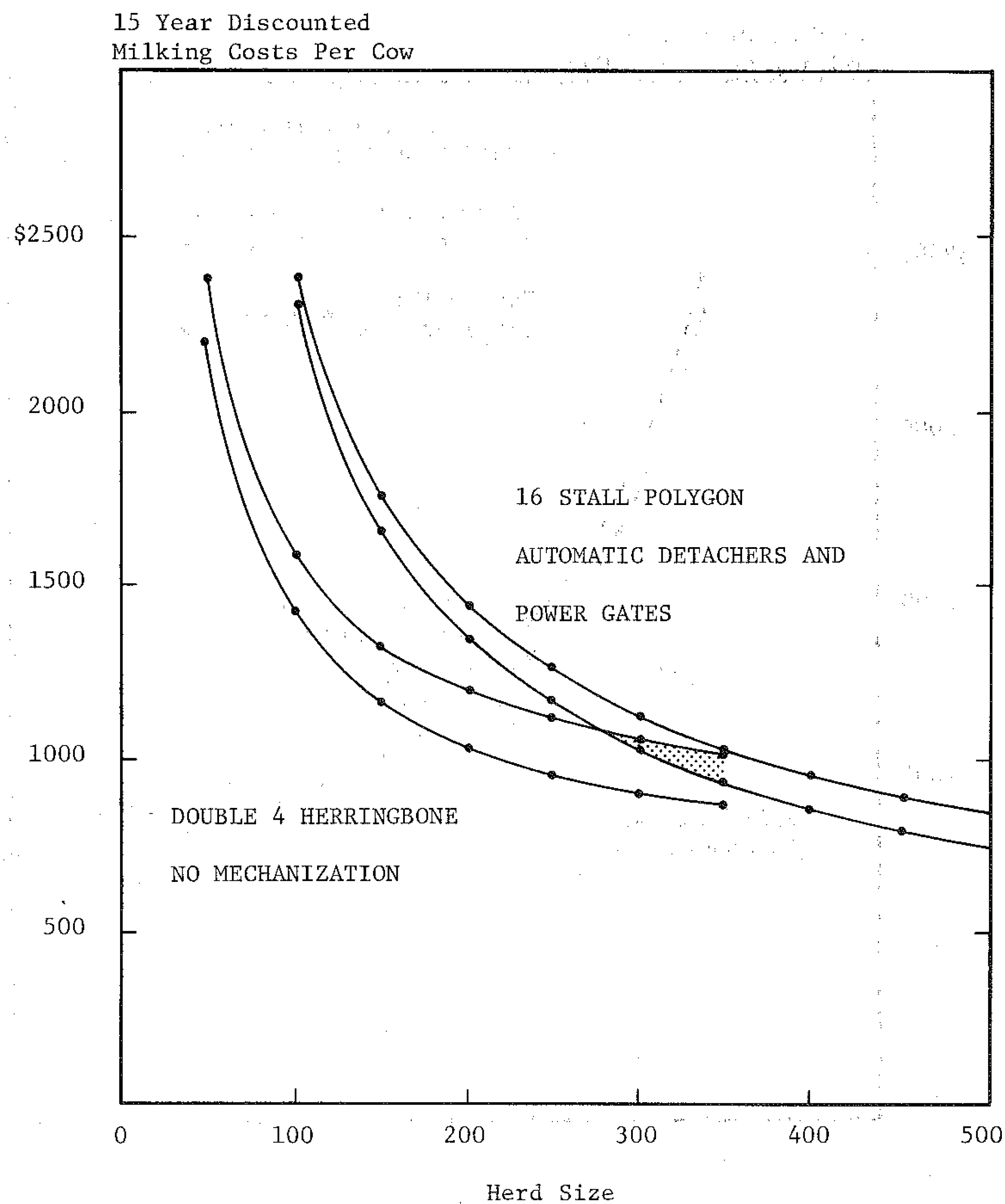


Figure 9. COMPARISON OF DOUBLE 4 HERRINGBONE, NO MECHANIZATION AND 16 STALL POLYGON
Washington, 1979



The degree of overlap between the cost ranges of the two systems is due in large part to the wide ranges in throughputs that each system has. If the cost ranges were narrowed without sacrificing knowledge about throughputs, a clearer impression of the strengths and weaknesses of each system (with regard to herd size) could be obtained.

One way to make such comparisons is to partition each system's cost range into three smaller ranges which correspond to the ability of a dairyman to milk at three different rates: average, faster than average and slower than average. This approach permits the comparison of milking systems on three different levels reflecting relative milking speed.

For example, the high and low 15 year discounted milking costs per cow for a herd of 50 cows milked with the herringbone double 4 system are $2,381 and $2,205 per cow, respectively. Dividing this range into three smaller ranges corresponding to throughput performance gives the following results:

Milking speed	Steady state throughput range (cows/hour)	Range of 15 year discounted milking costs per cow
Fast	40.7 - 44.0	$2,308 - $2,369
Average	37.3 - 40.7	$2,369 - $2,431
Slow	34.0 - 37.3	$2,431 - $2,492

Averaging the high and low bounds of each of the three cost ranges provides a mean total cost per cow for each milking speed:

Milking speed	Average steady state throughput (cows/hour)	Average 15 year discounted milking costs per cow
Faster than average	42.3	$2,238
Average	39.0	$2,400
Slower than average	35.7	$2,462

These figures have been used to determine which systems are most cost efficient for each herd size. The results are presented in Tables 25-27, which list the least cost system for each herd size as well as the other competing systems whose total milking costs fall within $10,000 of the least cost sytem over a 15 year period.

As illustrated in Table 25, for example, the 12 stall trigon parlor equipped with detachers and power gates is the least cost system for dairymen who milk at an average speed and have a herd size of 250. The second best system is the herringbone double 6 with detachers, power gates and feedbowl covers. With a milking cost of $1,029 per cow the double 4 system is $21 less expensive than the herringbone double 6 system which has a milking cost of $1,050 per cow. Multiplying the $21 difference by 250 cows shows that using the trigon parlor should be $5,250 less expensive in present value terms using a 15 year planning horizon.

Table 25. AVERAGE MILKING SPEED

Herd Size	Least Cost Systems, Ranked in Order 1	2	3	4	5	6
50	Herringbone Double 4 (None) 2,281 (2.2)	Herringbone Double 6 Detachers* 2,949 (1.9)	Herringbone Double 6 Detachers, Power gates* 3,027 (1.9)			
75	Herringbone Double 4 (None) 1,759 (2.9)	Herringbone Double 6 Detachers* 2,158 (2.5)	Herringbone Double 6 Detachers, Power gates* 2,206 (2.4)			
100	Herringbone Double 4 (None) 1,499 (3.6)	Herringbone Double 6 Detachers* 1,763 (3.0)	Herringbone Double 6 Detachers, Power gates* 1,796 (3.0)			
150	Herringbone Double 4 (None) 1,238 (4.9)	Herringbone Double 6 Detachers* 1,367 (4.1)	Herringbone Double 6 Detachers, Power gates* 1,386 (4.0)			
200	Herringbone Double 4 (None) 1,107 (6.3)	Herringbone Double 6 Detachers* 1,169 (5.2)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers* 1,176 (4.9)			
250	Herringbone Double 4 (None) 1,029 (7.7)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers* 1,050 (6.0)	Herringbone Double 6 Detachers 1,051 (6.3)	Herringbone Double 6 Detachers, Power gates 1,057 (6.2)	Trigon 12 Stall Detachers, Power gates, Feedbowl covers 1,058 (5.2)	

The number in () equal the hours required per milking including start up and clean up.

Table 25 (continued) AVERAGE MILKING SPEED

Herd Size	Least Cost Systems, Ranked in Order 1	2	3	4	5	6
300	Trigon 12 Stall Detachers, Power gates, Feedbowl covers 958 (6.0)	Herringbone Double 6 Detachers Power gates, Feedbowl covers 966 (7.0)	Herringbone Double 6 Detachers 972 (7.3)	Herringbone Double 6 Detachers, Power gates 975 (7.2)	Herringbone Double 4 (None) 977 (9.0)	Herringbone Double 8 Detachers, Power gates, Feedbowl covers 987 (6.2)
350	Trigon 12 Stall Power gates, Feedbowl covers 886 (6.9)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers 905 (8.0)	Herringbone Double 8 Detachers Power gates, Feedbowl covers 914 (7.0)			
400	Trigon 12 Stall Detachers, Power gates, Feedbowl covers 832 (7.8)	Herringbone Double 8 Detachers, Power gates, Feedbowl covers* 859 (7.9)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers* 860 (9.0)			
450	Trigon 12 Stall Detachers, Power gates, Feedbowl covers 790 (8.6)	Herringbone Double 8 Detachers, Power gates, Feedbowl covers* 817 (8.8)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers* 825 (10.0)			
500	Trigon 12 Stall Detachers, Power gates, Feedbowl covers 756 (9.5)	Herringbone Double 8 Detachers, Power gates, Feedbowl covers* 782 (9.7)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers* 797 (11.1)			

*Not within $10,000.

Table 26. SLOW MILKING SPEED

Herd Size	Least Cost Systems, Ranked in Order 1	2	3	4	5
50	Herringbone Double 4 (None) 2,381 (2.4)	Herringbone Double 6 Detachers* 3,082 (2.2)	Herringbone Double 6 Detachers, Power gates* 3,139 (2.1)		
75	Herringbone Double 4 (None) 1,859 (3.2)	Herringbone Double 6 Detachers* 2,291 (2.8)	Herringbone Double 6 Detachers, Power gates* 2,318 (2.7)		
100	Herringbone Double 4 (None) 1,599 (3.9)	Herringbone Double 6 Detachers* 1,896 (3.5)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers* 1,899 (3.2)		
150	Herringbone Double 4 (None) 1,338 (5.4)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers* 1,477 (4.4)	Herringbone Double 6 Detachers, Power gates* 1,498 (4.7)		
200	Herringbone Double 4 (None) 1,207 (7.1)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers* 1,266 (5.6)	Trigon 12 Stall Detachers, Power gates, Feedbowl covers* 1,281 (4.9)		
250	Herringbone Double 4 (None) 1,129 (8.6)	Trigon 12 Stall Detachers, Power gates, Feedbowl covers 1,130 (5.9)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers 1,140 (6.8)	Herringbone Double 6 Detachers, Power gates 1,169 (7.2)	

The number in () equal the hours required per milking including start up and clean up.

Table 26 (continued) SLOW MILKING SPEED

Herd Size	Least Cost Systems, Ranked in Order 1	2	3	4	5
300	Trigon 12 Stall Detachers, Power gates, Feedbowl covers 1,030 (6.9)	Herringbone Double 6 Detachers, Power gates Feedbowl covers 1,056 (8.0)	Herringbone Double 4 (None)* 1,077 (10.2)		
350	Trigon 12 Stall Detachers, Power gates, Feedbowl covers 958 (7.8)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers* 995 (9.2)	Polygon 16 Stall Detachers, Power gates, Feedbowl covers* 1,024 (6.9)		
400	Trigon 12 Stall Detachers, Power gates, Feedbowl covers 904 (8.8)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers 950 (10.4)	Polygon 16 Stall Detachers, Power gates, Feedbowl covers* 953 (7.7)		
450	Trigon 12 Stall Detachers, Power gates, Feedbowl covers 862 (9.8)	Polygon 16 Stall Detachers, Power gates, Feedbowl covers* 898 (8.6)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers* 915 (11.6)		
500	Trigon 12 Stall Detachers, Power gates, Feedbowl covers 828 (10.8)	Polygon 16 Stall Detachers, Power gates, Feedbowl covers* 854 (9.4)	Herringbone Double 8 Detachers, Power gates, Feedbowl covers* 907 (12.0)		

*Not within $10,000.

Table 27. FAST MILKING SPEED

Herd Size	Least Cost Systems, Ranked in Order 1	2	3	4	5	6
50	Herringbone Double 4 (None) 2,205 (2.1)	Herringbone Double 6 Detachers* 2,867 (1.8)	Herringbone Double 6 Detachers, Power gates* 2,948 (1.7)			
75	Herringbone Double 4 (None) 1,683 (2.7)	Herringbone Double 6 Detachers* 2,076 (2.2)	Herringbone Double 6 Detachers, Power gates* 2,127 (2.2)			
100	Herringbone Double 4 (None) 1,423 (3.3)	Herringbone Double 6 Detachers* 1,681 (2.7)	Herringbone Double 6 Detachers, Power gates* 1,717 (2.7)			
150	Herringbone Double 4 (None) 1,162 (4.5)	Herringbone Double 6 Detachers* 1,285 (3.6)	Herringbone Double 6 Detachers, Power gates* 1,307 (3.6)			
200	Herringbone Double 4 (None) 1,031 (5.7)	Herringbone Double 6 Detachers* 1,087 (4.6)	Herringbone Double 6 Detachers, Power gates* 1,101 (4.5)			
250	Herringbone Double 4 (None) 953 (6.9)	Herringbone Double 6 Detachers 969 (5.5)	Herringbone Double 6 Detachers, Power gates 978 (5.4)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers 979 (5.3)		

The numbers in () equal the hours required per milking including start up and clean up.

Table 27 (continued) FAST MILKING SPEED

Herd Size	Least Cost Systems, Ranked in Order 1	2	3	4	5	6
300	Herringbone Double 6 Detachers 890 (6.4)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers 895 (6.2)	Herringbone Double 6 Detachers, Power gates 896 (6.3)	Herringbone Double 4 (None) 901 (8.2)	Trigon 12 Stall Detachers, Power gates, Feedbowl covers 908 (5.5)	Herringbone Double 8 Detachers, Power gates, Feedbowl covers 914 (5.4)
350	Herringbone Double 6 Detachers 833 (7.3)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers 834 (7.1)	Trigon 12 Stall Detachers, Power gates, Feedbowl covers 836 (6.2)	Herringbone Double 6 Detachers, Power gates 838 (7.2)	Herringbone Double 8 Detachers, Power gates, Feedbowl covers 841 (6.1)	
400	Trigon 12 Stall Detachers, Power gates, Feedbowl covers 782 (7.0)	Herringbone Double 8 Detachers, Power gates, Feedbowl covers 786 (6.8)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers 789 (8.0)	Herringbone Double 6 Detachers 791 (8.3)	Herringbone Double 6 Detachers, Power gates 794 (8.2)	
450	Trigon 12 Stall Detachers, Power gates, Feedbowl covers 740 (7.8)	Herringbone Double 8 Detachers, Power gates, Feedbowl covers 744 (7.6)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers 754 (8.8)	Herringbone Double 6 Detachers 758 (9.2)	Herringbone Double 6 Detachers, Power gates 760 (9.1)	
500	Trigon 12 Stall Detachers, Power gates, Feedbowl covers 706 (8.5)	Herringbone Double 8 Detachers, Power gates, Feedbowl covers 709 (8.3)	Herringbone Double 6 Detachers, Power gates, Feedbowl covers 726 (9.7)			

*Not within $10,000.

If one is planning for a milking herd of 300 cows there are six different milking systems which have very similar costs if one assumes average milking speed. These are in order:

(1) 12 Stall Trigon with detachers, power gates and feedbowl covers
$958 per cow

(2) Herringbone, Double 6 with detachers, power gates and feedbowl covers
$966 per cow

(3) Herringbone, Double 6 with detachers only
$972 per cow

(4) Herringbone, Double 6 with detachers and power gates
$975 per cow

(5) Herringbone, Double 4
$977 per cow

(6) Herringbone, Double 8 with detachers, power gates and feedbowl covers
$987 per cow

These six systems compete within a range of $29 per cow or a total of $8,700 (300 cows) in present value terms for a 15 year planning horizon.

Study of the data in Tables 25-27 suggest that dairymen with herd sizes of 150-300 are faced with a large number of competitive options with similar levels of costs. Part of this results from the decision to consider three combinations of mechanization with a herringbone double 6 parlor in this analysis. Another factor is the choice of parlor sizes to be evaluated. Other smaller herringbone and some side-opening parlors would probably have similar but higher costs for herd sizes up to 100 or 150. The smaller number of alternative systems for herds over 350 cows highlights an area which future milking system technology must focus upon. Presently the number of alternatives for milking large numbers of cows with comparable throughputs per hour are few in number without going to a second parlor.

Management which results in faster than average milking speeds enables a dairyman to consider a relatively large number of milking system alternatives. Larger parlors and increased mechanization can be justified if the dairyman is in a position to take full advantage of the potential time savings that they offer. The amount of time spent to complete a milking shift is a related decision variable of importance.

Management Implications

The results of this study indicate that the herringbone double 4, 6 and 8 systems and the 12 stall trigon system are the most economical milking systems to consider for dairy herds of 50 to 500 cows. Sixteen stall polygon and herringbone double 10 systems should not be given serious consideration unless factors unrelated to cost play a major role. If, for example, a dairyman wanted to minimize the time spent milking cows and costs were not important to him, he would probably choose from among systems capable of the highest throughputs. The herringbone double 10 and 16 stall polygon systems are capable of the highest throughputs but they also have the highest fixed and total costs for the range of herd sizes considered.

Competitive milking systems were defined as those whose total costs discounted over 15 years fall within $10,000 of the least cost system's total discounted 15 year costs at a given herd size and milking speed. The 16 stall polygon was not competitive under any of the conditions assumed in this study because of its relatively high initial capital requirement. Neither was the herringbone double 10 system competitive under the conditions considered in this study. Any of the following factors can eliminate a highly vulnerable throughput system like the double 10 from consideration: inability of operator to milk at a high speed, lack of uniformity among individual cow milking times or poor cow movement into and out of the parlor.

The herringbone double 4 parlor with no mechanization is the least cost system for herds up to 200 cows. In fact, the double 4 system has no close competitors until a herd size of 250 is reached. The most highly mechanized form of system, the herringbone, double 6 with automatic detachers, power gates and feedbowl covers, is to be preferred unless the operator is a faster than average milker. In this case he might have lower costs with detachers only.

Herds of 300 or more cows are most economically milked in a trigon parlor with detachers and power gates. A fast milker might be better off in a double 6 in the 300-350 herd size range. Per-cow costs suggest that automatic detachers in a double 6 herringbone parlor are sufficient for herd sizes of 150 to 200 cows. Beyond that size a combination of detachers, power gates and feedbowl covers is advisable.

Variation in costs among the three double 6 systems illustrates the "penalty costs" of choosing one of the less efficient sets of mechanization for a given parlor. With average milking speed the highest penalty occurs among the double 6 mechanization options for a herd size of 300. A combination of detachers, power gates and feedbowl covers could save $2,700 in present value terms over 15 years compared with a double 6 featuring detachers and power gates. This penalty cost applies only when the parlor throughputs assumed in this study are realized.

Another way of looking at penalty costs is associated with milking speed differences. By comparing each system's costs per cow for the three milking speeds one can see potential gains or losses. For example, a herringbone double 4's per-cow costs for a herd size of 100 are as follows:

Milking speed	Average 15 year discounted milking cost per cow
Fast	$1,423
Average	$1,499
Slow	$1,599

The penalty cost associated with milking cows at a slow rather than average speed is $100 per cow for a herd size of 100. For the entire herd the discounted costs over 15 years amount to $10,000. In general the penalty costs associated with slower milking speeds are approximately $70 per cow for a shift of one level of performance below another.

Management that leads to slower milking has fewer milking system alternatives which are competitive. Figure 10 identifies the least cost systems for average milking speeds for each herd size between 50 and 500 cows. Similar information is presented for dairymen who expect somewhat slower than average milking speeds in Figure 11 and for dairymen with faster than average milking speeds in Figure 12.

A review of the data in Tables 25-27 also indicates fewer competitive alternatives at any given herd size for slower milking speeds. Notably, the trigon system has no competitors beyond a herd size of 350 in conditions that restrict parlor throughputs below the average rate.

The 12 stall trigon parlor's general adaptability is interesting when compared with other large parlors which have high fixed costs. In general, the parlors with more than 12 stalls are better suited to management that is capable of faster than average milking. Regardless of fast, average or slow throughput rates the double 10 system's costs never fall within $10,000 of the least cost system. The trigon system, however, seems to become more competitive as milking speed decreases. It has no close competitors in herd sizes exceeding 350 when milking speed is slower than average. The reason for the trigon becoming more rather than less competitive as milking speed decreases is that it has a smaller range of throughput capabilities than similar large parlors. The smaller fluctuation in throughputs is due to the fact that three rather than two strings of cows are milked at a time. A slow milking cow will hold up seven other cows in a double 8 but only three other cows in a 12 stall trigon. This suggests that big herds which have a large variation in individual cow milking time will be milked more easily in a trigon parlor, everything else being equal.

It is still premature to declare the trigon parlor as the least cost system for average or slow-milking herds of 250 to 500. Not enough trigon systems have been observed under practical farm conditions to assure that the assumed throughput range is realistic. The strongest recommendation that can be made presently is that the trigon parlor deserves serious consideration by any dairyman who is considering new milking facilities for a herd of 250 to 500 cows. The logic of the way the system works and limited observation of the system in use, confirm this positive recommendation.

Regional Differences

The results of this study are most applicable to the Pacific Northwest dairy region. Use of these results in other geographic areas requires making adjustments in the input data which are likely to vary according to location. The most obvious differences will be in parlor and holding pen construction and related costs.

A more important regional factor is the cost of labor. Since milking wages constitute over 90 percent of variable operating costs, any change will directly influence the selection of least cost systems. In regions where labor costs are below $6 per hour the low fixed cost and higher variable cost systems like the herringbone double 4 and double 6 will become more attractive to dairymen. In areas having labor costs over $6 per hour the high fixed cost and lower variable cost systems like the herringbone double 8 and 12 stall trigon will turn out to be least cost over a wider range of herd sizes.

Figure 10. LEAST COST MILKING SYSTEMS FOR DAIRYMEN WITH AVERAGE MILKING SPEED Washington, 1979

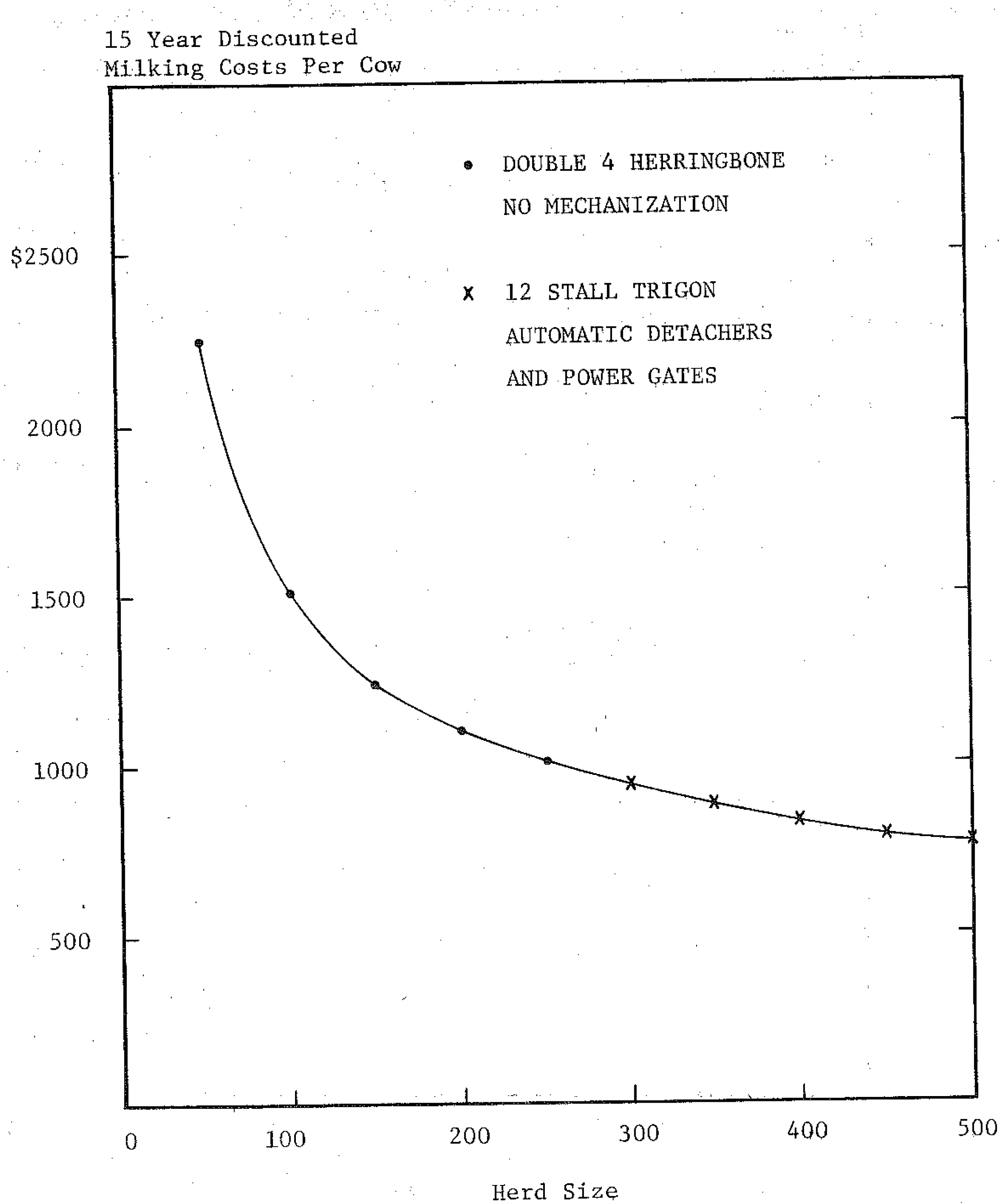


Figure 11. LEAST COST MILKING SYSTEMS FOR DAIRYMEN WITH SLOWER THAN AVERAGE MILKING SPEED
Washington, 1979

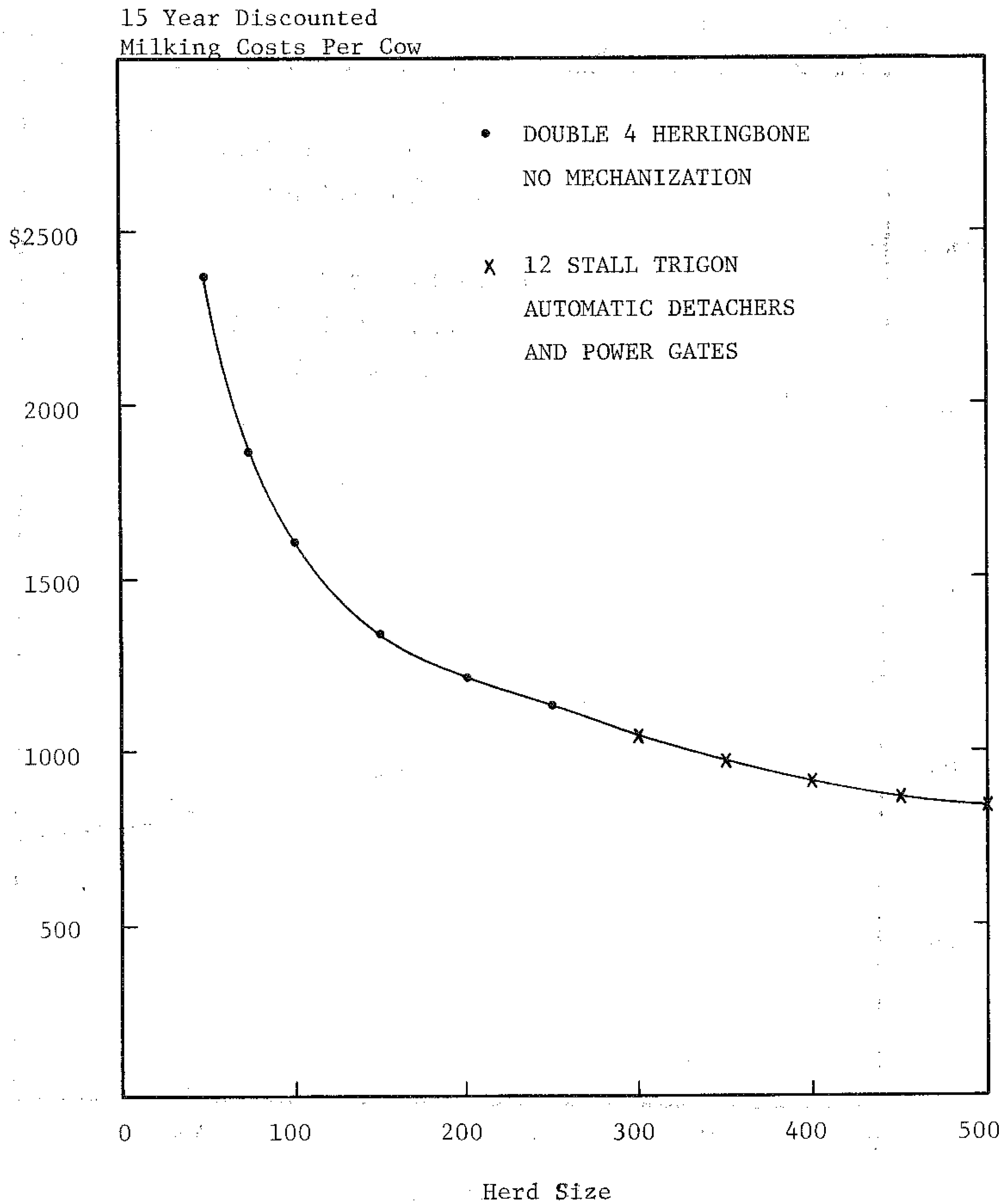
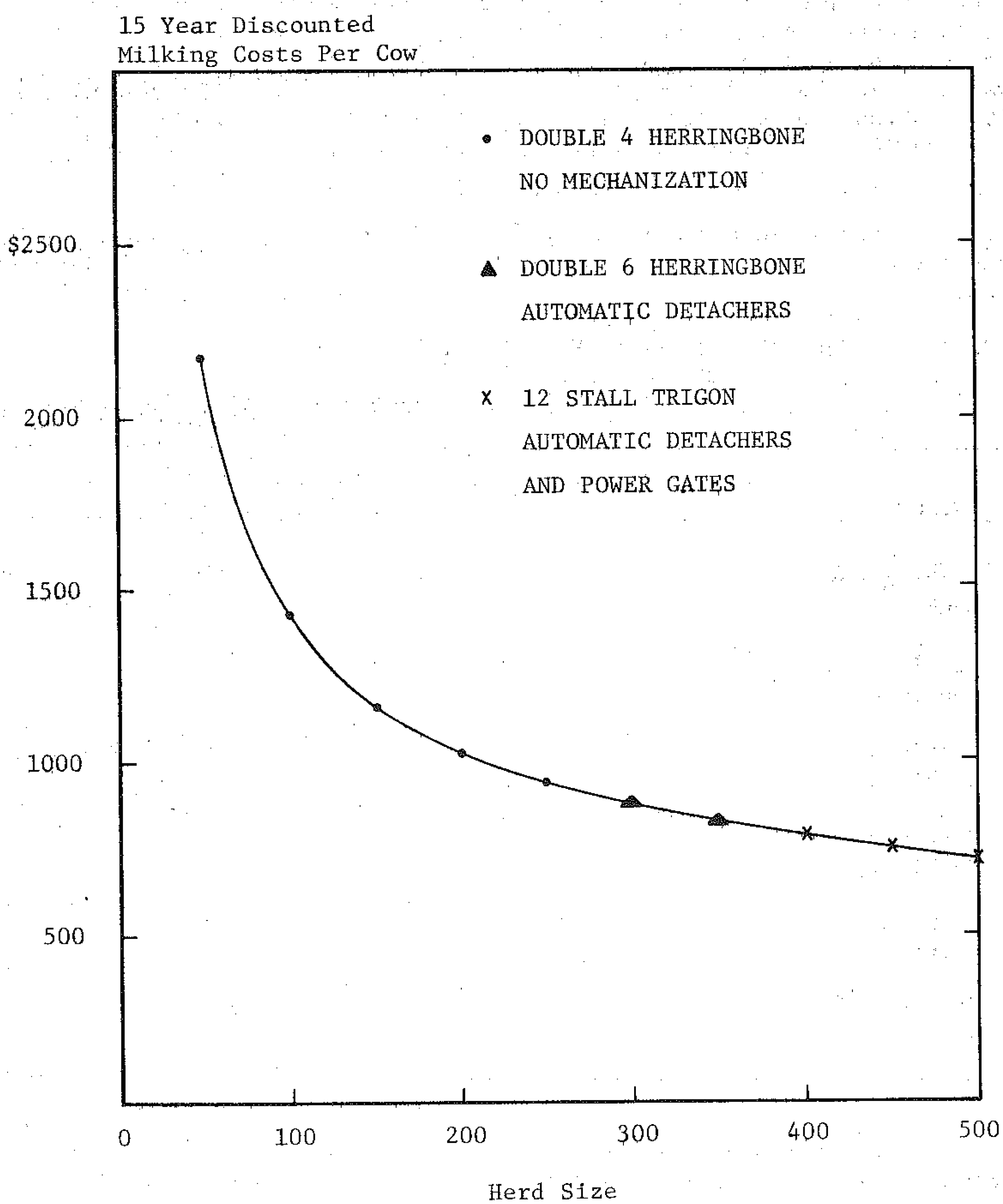


Figure 12. LEAST COST MILKING SYSTEMS FOR DAIRYMEN WITH FASTER THAN AVERAGE MILKING SPEED
Washington, 1979



Breakeven Analysis for Crowd Gate

Regional throughput variation could result from construction differences. As previously mentioned, colder climates requiring walled-in parlors will make the use of crowd gates more helpful than with open-ended parlors. Breakeven analysis may be used to determine how much milking speed would have to be improved to justify the addition of a crowd gate to each parlor.

The addition of a crowd gate to the herringbone double 4 parlor required an average initial outlay of $4,600. Multiplying this by the DCF expansion factor of 2.1062 indicates that the 15 year discounted costs related to adding a crowd gate have a net present value of $9,689. In order for the crowd gate investment to break even it must bring about labor savings having the same present value. Each hour of milking labor has a 15 year discounted value of $25,319 (= $6/hour wage rate x 0.76 after-tax adjustment x 730 milkings/year x 7.6061, the 15 year, 10 percent present value adjustment). Therefore a crowd gate must save $\frac{\$9,689}{\$25,319}$ = 0.38 hour = 23 minutes of milking time per milking before it can be economically justified. Breakeven time savings required for each parlor to make the addition of a crowd gate feasible are presented in Table 28.

Table 28. TIME SAVINGS PER MILKING REQUIRED TO BREAK EVEN ON A CROWD GATE INVESTMENT
6 Selected Milking Parlors, Washington, 1979

Parlor	Required time savings per milking
	minutes
Herringbone Double 4	23
Herringbone Double 6	25
Herringbone Double 8	27
Herringbone Double 10	29
12 Stall Trigon	34
16 Stall Polygon	43

These time savings per milking can be translated into steady state throughput improvements if herd size is specified. Since every system has a high and low throughput range, the two steady state improvement rates obtained will define a range of throughput improvement needed to justify crowd gate investment. A herringbone double 4 parlor with 100 cows is used to illustrate the procedures:

Fast steady state throughput = 44 cows/hour

$$\text{Fast steady state milking time} = \frac{100}{44} = 2.27 \text{ hours}$$

Required time savings = 0.38 hour

2.27 hours - 0.38 hour = 1.89 hours

$$\frac{100 \text{ cows}}{1.89 \text{ hours}} = 52.9 \text{ cows/hour (with crowd gate)}$$

$$\underline{-44.0 \text{ cows/hour}} \text{ (without crowd gate)}$$

$$\underline{\underline{8.9 \text{ cows/hour}}} = \text{required steady state improvement}$$

Slow steady state throughput = 34 cows/hour

$$\text{Slow steady state milking time} = \frac{100}{34} = 2.94 \text{ hours}$$

Required time savings = 0.38 hour

2.94 hours - 0.38 hour = 2.56 hours

$$\frac{100 \text{ cows}}{2.56 \text{ hours}} = 39.1 \text{ cows/hour (with crowd gate)}$$

$$\underline{-34.0 \text{ cows/hour}} \text{ (without crowd gate)}$$

$$\underline{\underline{5.1 \text{ cows/hour}}} = \text{required steady state improvement}$$

Steady state throughput improvement range
required to pay for crowd gate = $\underline{\underline{5.1 \text{ to } 8.9 \text{ cows/hour}}}$

The throughput improvement required is less when starting with slower milking speeds. An already efficient system requires substantial change to justify further capital expenditure on a crowd gate. The range in improvements in cows milked per hour to break even on a crowd gate investment for different systems is presented in Table 29. In general as herd size increases, the improvement in throughput required to break even decreases.

A complete analysis would require actual observation of throughputs in walled-in parlors with and without crowd gates. Larger, slower-milking herds are more likely to benefit from adding a crowd gate than smaller, faster-milking herds.

Table 29. BREAK EVEN ANALYSIS ON INCREASES IN STEADY STATE THROUGHPUT NEEDED TO JUSTIFY CROWD GATE INVESTMENT
6 Selected Milking Systems, Washington, 1979

	Milking system					
Herd Size	Herringbone Double 4 (None)	Herringbone Double 6 Detachers	Herringbone Double 6 Detachers, Power gates	Herringbone Double 6 Detachers, Power gates, Feedbowl covers	Herringbone Double 8 Detachers, Power gates, Feedbowl covers	Trigon 12 Stall Detachers, Power gates, Feedbowl covers
			cows per hour			
50	12.0-22.3					
75	7.1-12.7					
100	5.1- 8.9					
150	3.2- 5.6	5.0-11.5	5.5-12.0	6.4-12.9		
200	2.4- 4.0	3.6- 8.3	4.0- 8.6	4.6- 9.2		
250	1.9- 3.2	2.9- 6.4	3.2- 6.7	3.6- 7.1	4.7-12.0	7.8-14.9
300		2.3- 5.3	2.6- 5.4	3.0- 5.8	3.9- 9.8	6.4-12.0
350		2.0- 4.4	2.2- 4.6	2.5- 4.9	3.3- 8.2	5.4-10.1
400		1.7- 3.9	1.9- 4.0	2.2- 4.3	2.9- 7.1	4.6- 8.6
450					2.5- 6.2	4.1- 7.6
500					2.3- 5.6	3.6- 6.8

Construction Costs

The capital cost survey made for this study indicated that economies of size do exist in parlor construction. The following table summarizes the average cost per square foot for construction of the six different sizes of parlors considered in this study.

Table 30. AVERAGE CONSTRUCTION COSTS PER SQUARE FOOT OF PARLOR SPACE
6 Selected Parlors, Washington, 1979

Parlor type	Parlor area	Average parlor construction cost	Cost per square foot
	square feet		
Herringbone Double 4	392	$12,315	$31.44
Herringbone Double 6	497	14,157	28.47
Herringbone Double 8	603	16,340	27.11
Herringbone Double 10	708	18,048	25.48
12 Stall Trigon	912	19,236	21.09
16 Stall Polygon	1,653	28,657	17.34

Parlor construction costs declined on a square foot basis as parlor size increased. These results suggest the need to get bids on specific systems rather than estimating construction costs by applying constant cost factors to physical dimensions (Matulich, Carman and Carter).

Recognize Variability

The use of throughput ranges rather than point estimates has allowed greater insight into the kind of cost variability one can expect to find in the field. The applicability of these cost ranges could be improved by recognizing two other factors which would at the same time greatly complicate analysis. First, steady state throughputs are likely to decrease as the length of the milking shift increases. An Arizona study (Armstrong) indicates that a milking operator's efficiency can decline up to 30-40 percent by the seventh hour of an eight hour milking shift. This means that for a given herd size the milking systems with lower throughputs may require even more time per milking. Thus, such a system could prove to be more costly than a system with a higher capital cost allowing higher throughputs per hour. The faster systems, requiring less milking time, can be operated at a higher average point on an efficiency curve. As the length of the milking shift increases, efficiency in milking should be expected to decrease.

Second, it may be unrealistic to assume that milkers in the different systems are paid the same wages. If larger and faster systems require more highly skilled and better paid labor, then for any given herd size this analysis has overstated the cost competitiveness of these larger systems. These are the kinds of qualitative differences which dairymen must consider in making these major investment decisions.

Two other factors have been left out of the study because they are nearly impossible to value in dollar terms and because they will vary substantially between herds and managers. The first factor is operator comfort. A dairyman who really dislikes milking might justify to himself the construction of a larger and potentially faster system than that suggested by cost analysis alone.

The second possibility not considered is that diseconomies of size may add to milking costs at some point as herd size increases. The results presented in Figures 10-12 suggest that milking costs per cow in the least cost systems decline continuously over the herd sizes considered but at a decreasing rate. Costs per cow for a herd of 500 are about one third of the same costs for a herd of 50. But the budgets used in this analysis fail to allow for two factors which could increase milking costs per cow:

1. Milking labor for larger herds may be more difficult to locate, manage and retain and require higher wages per hour.

2. Larger and faster systems used in big herds may have a negative effect on health and milk quality as individual attention to cows is reduced. Milk production levels may be reduced as well.

The first factor is likely to hold constant for any given herd size, regardless of the milking system used. But the second factor may be correlated with the rate of throughput attained with the milking system. If the costs associated with this factor are significant they may cause the slower systems to become more attractive than this analysis suggests.

The results of a study of this type are very sensitive to the throughput rates assumed for each system. The estimates for the polygon and trigon systems were based on quite limited information. Future analysis would benefit from re-examining these throughput ranges and any others which are subject to technological change. Milking speeds are likely to continue to increase as technology changes in the future.

APPENDIX A

Figure 13. HERRINGBONE DOUBLE 4 PARLOR FLOORPLAN

Parlor length: 23 feet, 6 inches

Parlor width: 16 feet, 8 inches

Milking pit length: 18 feet, 9 inches

Milking pit width: 6 feet

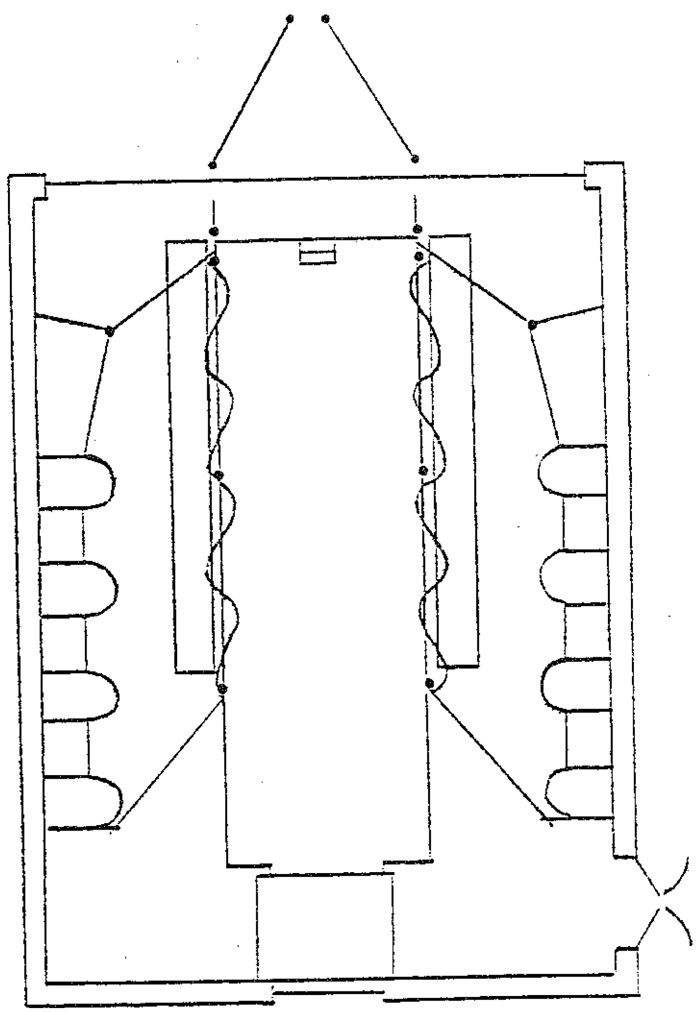


Figure 14. HERRINGBONE DOUBLE 6 PARLOR FLOORPLAN

Parlor length: 29 feet, 10 inches

Parlor width: 16 feet, 8 inches

Milking pit length: 25 feet, 1 inch

Milking pit width: 6 feet

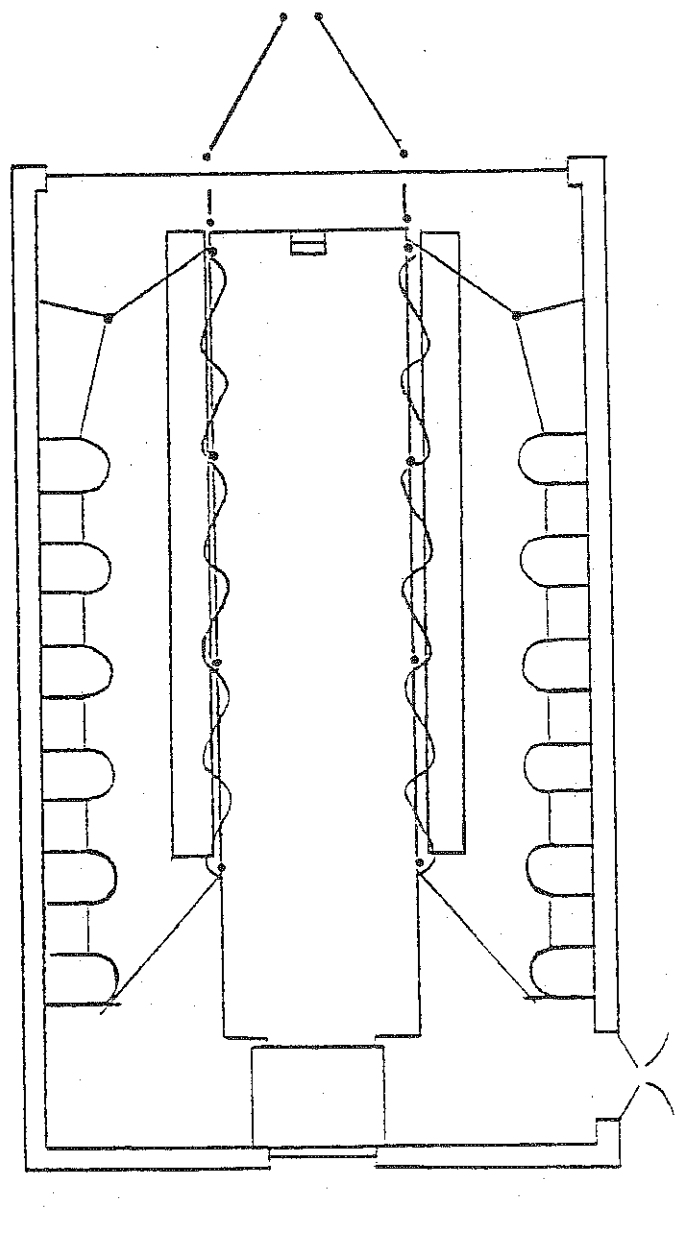


Figure 15. HERRINGBONE DOUBLE 8 PARLOR FLOORPLAN

Parlor length: 36 feet, 2 inches

Parlor width: 16 feet, 8 inches

Milking pit length: 31 feet, 5 inches

Milking pit width: 6 feet

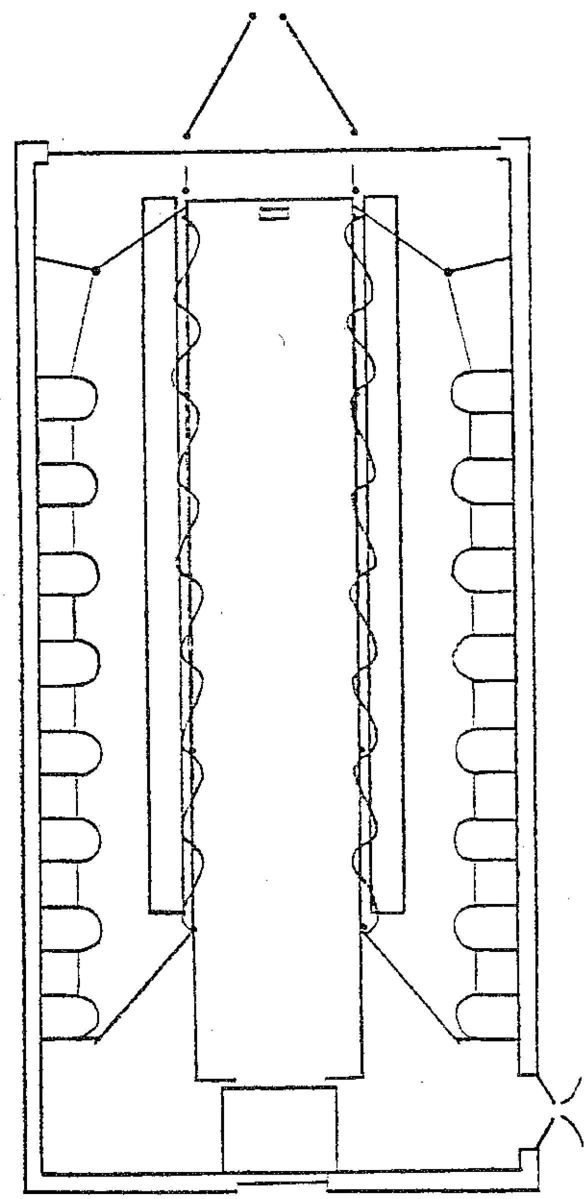


Figure 16. HERRINGBONE DOUBLE 10 PARLOR FLOORPLAN

Parlor length: 42 feet, 6 inches

Parlor width: 16 feet, 8 inches

Milking pit length: 37 feet, 9 inches

Milking pit width: 6 feet

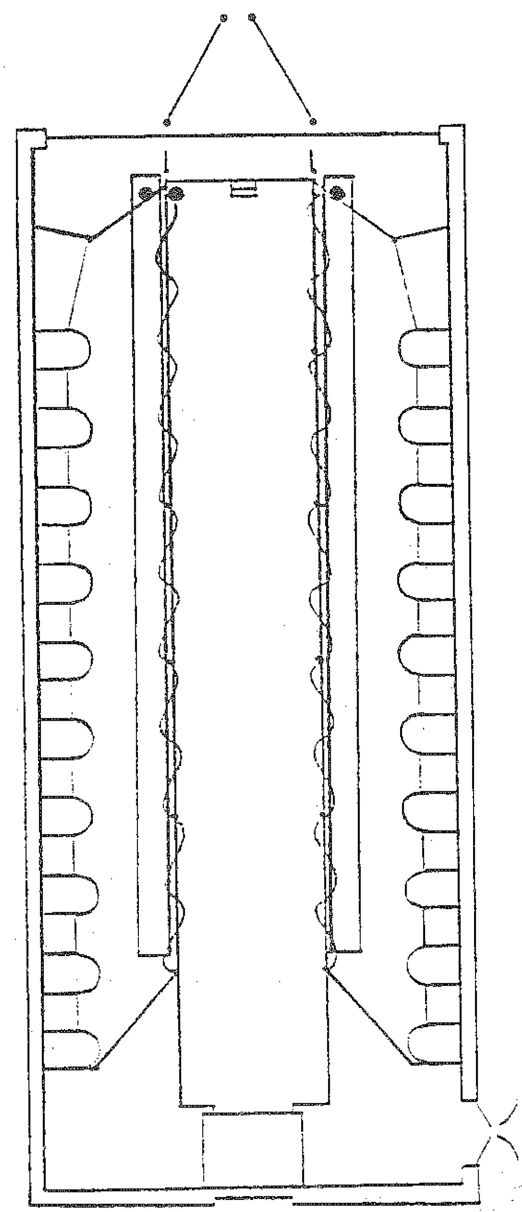


Figure 17. 12 STALL TRIGON PARLOR FLOORPLAN

Parlor length:	32 feet
Parlor width:	28 feet, 6 inches
Lengths of milking pit sides:	15 feet
	23 feet
	16 feet, 6 inches

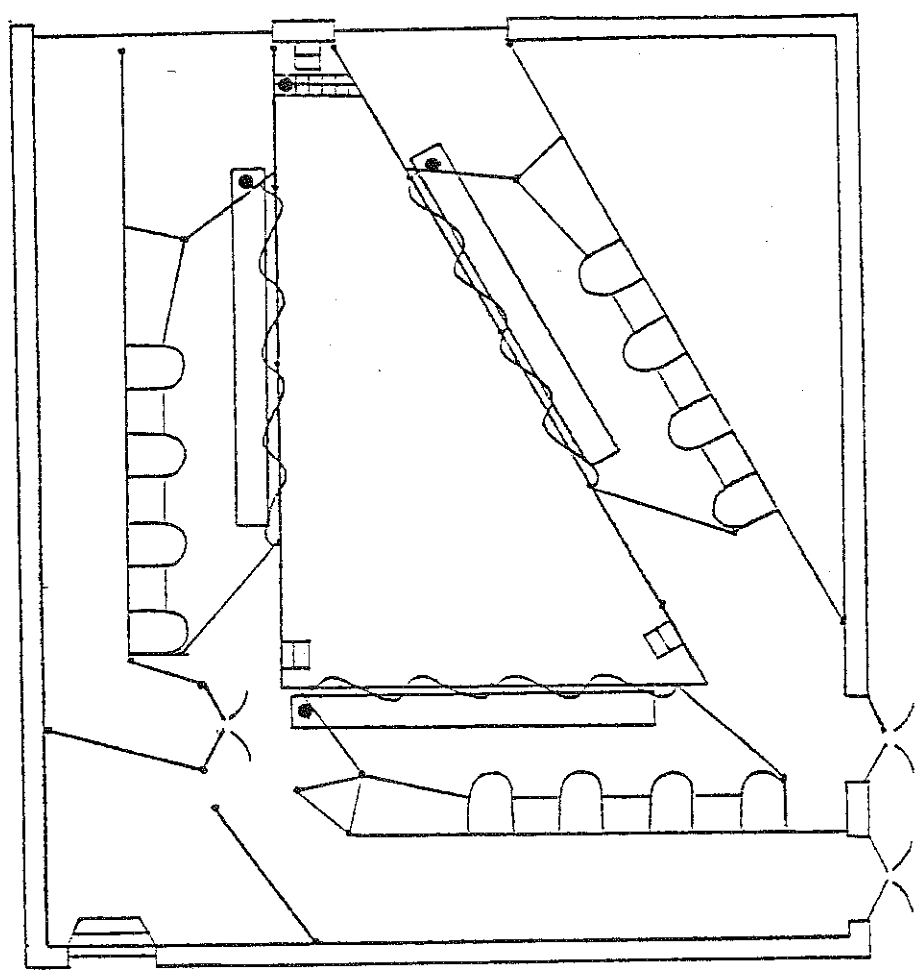


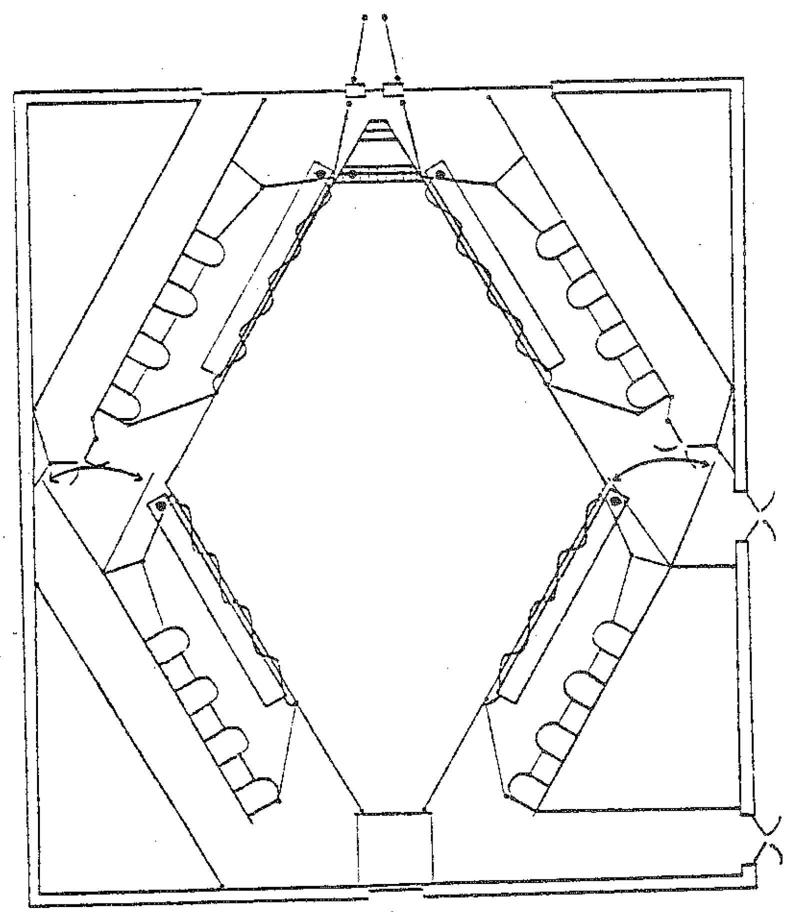
Figure 18. 16 STALL POLYGON PARLOR FLOORPLAN

Parlor length: 43 feet, 6 inches

Parlor width: 38 feet

Milking pit length: 38 feet

Milking pit width: 24 feet



APPENDIX B

Table 31. ESTIMATED CAPITAL COSTS, 12 STALL TRIGON PARLOR
Washington, 1978

Component	Number of estimates	Mean of estimates	3/4 Quartile Deviation	Cost Range
Parlor and holding pen construction	3	$28,500	$1,100	$27,400-29,600
Parlor painting	1	2,600	0	2,600
Plumbing-heating-electrical	3	6,700	800	5,900- 7,500
Parlor equipment	5	15,000	950	14,050-15,950
Milking equipment	4	16,000	550	15,450-16,550
Complete unmechanized parlor		68,800	3,400	65,400-72,200
Mechanization				
Economy automatic detachers	4	2,800	200	2,600- 3,000
Deluxe automatic detachers	4	12,500	200	12,300-12,700
Power gates	4	3,000	50	2,950- 3,050
Feedbowl covers	3	2,000	250	1,750- 2,250
Stimulating sprays	2	2,000	250	1,750- 2,250
Crowd gate	5	6,800	1,500	5,300- 8,300

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