Management and Economics of On Farm Pasteurizers

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The goal of a calf rearing program should be to optimize growth and health while minimizing risk and cost. Economics of a calf rearing program should be measured in terms of cost per lb. of gain and total cost to rear calves to a given weight/age, including mortality charges. As the price of milk replacer ingredients has increased calf growers have looked towards utilization of unsaleable milk from fresh cows and those treated with antibiotics as a source of economical nutrients. However, the practice of feeding raw milk to calves is not recommended due to the potential for disease transmission. Fortunately, pasteurizers have become commercially available that are well suited to treating the volumes of waste milk found on dairy farms and many calf raising operations.

The purpose of this presentation is to review the information about calf feeding systems using waste milk including potential benefits and risks. Recommended protocols for managing uncertainty associated with these feeding systems will be discussed.

Benefits of pasteurized waste milk

Calves fed whole milk grow better than calves fed traditional milk replacers have containing 20% fat and 20% protein. This is due to the higher level of nutrients found in whole milk as shown in table 1. (It's important to note that composition of waste milk can deviate significantly from saleable milk as will be demonstrated later in this manuscript.) In a study involving over 400 calves, Godden et al. (2005) found that calves fed pasteurized waste milk grew .26lb./day more and also had lower incidence of health problems and mortality than those receiving milk replacer. Differences are probably related to increased nutrient intake by calves fed waste milk. Scott et al.

(2006) observed that there was no difference in growth of calves fed milk replacers or waste milk on an isocaloric and equal solids basis.

Table 1. Composition of waste milk and milk replacer

Item	Composition	
Whole Milk	As is basis	DM Basis
Solids%	12.0 – 13	100.0
Protein %	3.2 – 3.7	26.7 – 27.6
Fat%	3.5 - 4.0	29.2 – 29.8
Lactose %	4.5 – 4.7	37.5 – 38
Ash %	.7 – 1.0%	5.8 – 7.4
Milk Replacer – 20:20		
Solids%	95.0	100.0
Protein%	20.0	21.0
Fat%	20	21.0
Lactose%	45.0	47.4
Ash	10.1	10.6

Risks associated with waste milk feeding

Risks include antibiotic and bacterial contamination of waste milk and variations in both the supply and nutrient content of waste milk. Waste milk is comprised of "fresh" cow milk and that from cows treated with antibiotics. The impact of antibiotics on digestive function and antibiotic resistance in calves appears minimal but has not been determined. Bacterial content of waste milk prior to pasteurization is very variable ranging from less than 50,000 colony forming units (cfu)/ml to more than a 50 million cfu/ml. Studies in California (Jamaluddin , 1996) and Wisconsin (Jorgensen et al, 2005) have isolated Salmonella, Mycoplasma, E. coli, Mycobacterium and other organisms of concern in raw waste milk. Fortunately properly operating pasteurizers successfully kill these organisms and are able to reduce standard plate counts (SPC) of waste milk to acceptable levels.

Waste milk can be a poorly defined liquid in many cases. Studies by Virginia (Scott, 2006) and Wisconsin workers (Jorgensen, 2005) revealed that fat content varied between 1.1% and 11% and protein between 2.9% and 4.7% depending on number of fresh cows being milked and amount of water during flushing of milk lines at the end of each milking. In addition to quality concerns, supply of waste milk varies considerably. Blosser (1979) estimated that each cow generates between 48 and 136lb of waste milk per lactation. In a study of North Carolina and California dairy farms, Scott (2006) found that availability of waste milk per calf per day ranged from to 5.6lb to more than 20 lb... Dealing with these uncertainties in a calf feeding program can be an exceptional management challenge.

Managing the feeding program using pasteurized waste milk

Batch and High Temperature Short Time (HTST) pasteurizers are the most prevalent systems in the U.S. When properly installed and maintained they will successful eliminate disease transmission concerns. Pasteurization occurs when milk is held for the recommended temperature for the desired time. **Pasteurization does not sterilize milk!** In properly operating systems a pasteurizer destroys 98 to 99% of the bacteria. If pre-pasteurization counts exceed 2,000,000 cfu/ml a post-pasteurization SPC goal of 20,000 cfu/ml may not be achieved.

Batch pasteurizers operate much the same as a double boiler on a stove top. They must heat and maintain milk at a temperature of 145°F for 30 minutes. Milk must be agitated to assure that there are no "dead" spots and that the head space above the level of the milk reaches pasteurization temperature as well to assure that milk is not contaminated after pasteurization. Batch systems are generally less expensive and simpler to operate but require manually cleaning.

The HTST units operate similar to the plate cooler in the milking system except in reverse. They must heat milk to 161°F for 15 seconds. Their operation and cleaning is more readily automated and they can process larger volumes of milk more quickly. Temperature is monitored by in-line thermometers and if inadequate the milk can be recirculated through the head exchanger by use of a diversion valve. These systems are also more expensive and require adequate hot water supplies beyond that used by the milking system.

It is logical that waste milk be treated with the same care as that given to saleable milk with care given to addressing process control in handling the milk from the cow's teat until it's consumed by the calf. The following components and management should be considered essential for maintaining milk quality in the waste milk feeding system.

- Waste milk receiving vessel. Collect and cool waste milk as soon as possible after milking. Holding milk at room temperature in the parlor until the end of milk is not recommended as SPC can exceed several million within a few hours of harvest. If there will be a delay of more than 2 hours between milking and pasteurization the waste milk should be cooled. Recognize that pasteurization of cooled milk increases energy expended and extends time required for pasteurization. Stainless steel or plastic tanks are used to hold waste milk prior to pasteurization. Provisions should be made for cleaning receiving vessels and all lines used to transfer milk each time milk is pasteurized.
- The pasteurizer. Equipment must be installed in accordance with manufacturer's specifications. In attempt to reduce costs, it's not uncommon to observe that shortcuts have been taken such as use of inadequate electrical service or provision of a marginally adequate hot water supply. Adequate hot water (170°F to 180°F) is important for proper operation of HTST units and cleaning and sanitizing of all milk contact surfaces. Closely follow manufacturer's instructions for operation.
    - Recording charts should be used to monitor function and assure that the correct time-temperature was achieved.
    - Use a digital thermometer to verify accuracy of the recording thermometer.
    - Function is verified by sending samples to a laboratory for measurement of:
        - Standard plate count. A reasonable goal is less than 20,000 cfu/ml.
        - Alkaline phosphatase. This is an enzyme present in milk which if properly heated is destroyed. A reasonable goal is less than 500 mUnits/ml.
- Post pasteurization. After pasteurization milk should be cooled to 110°F and fed as soon as possible. If feeding is delayed by more than one hour it should be cooled to <40oF. Vessels receiving pasteurized must be cleaned and sanitized. Studies of pasteurizer systems in North Carolina and California (Scott 2006) revealed that SPC counts

can return to levels exceeding 100,000 cfu/ml within one hour of pasteurization if receiving tanks, buckets or bottle are unclean.

- Sanitation of receiving vessels and pasteurizers. All milk contact surfaces should be flushed with potable water after emptying followed by thorough scrubbing with a detergent solution containing sufficient sodium hypochlorite to provide 110 ppm chlorine. Water temperature should be 167oF. Remove any gaskets and clean by hand. Follow with a potable water rinse and acid sanitizer and drain. Cover all vessels to prevent exposure of milk surfaces to flies and other insects.
    - Although cleaning of HTST units can be automated several important factors should be considered to keep equipment operating to its designed capacity.
        - Clean after each use.
        - Use cleaners and sanitizers in accordance with manufacturer's instructions. This commonly includes use of an alkali detergent followed by an acid rinse.
        - Most machines recommend keeping water temperatures below 180°F but above 170.
        - Once pasteurization is complete immediately begin flushing the system with water until it runs clear. Follow manufacturer instructions which generally recommend cleaning with the alkali detergent for at least 30 minutes, draining and followed by the acid rinse.
- Establish a quality control testing program with a reputable laboratory. During the first month of using the pasteurizer, consider obtaining three samples per day once a week. Measure standard plate count, fat % and protein % and total solids for each sample.
    - Pre pasteurization sample to evaluate procedures for obtaining and storing waste milk. SPC above 2,000,000 cfu/ml are unacceptable. Pasteurization can be expected to kill 99% of the organisms, leaving 20,000 cfu/ml. Higher counts indicate excessive holding time at temperatures exceeding 40oF, unsanitary holding vessels or both.
    - Post pasteurization sample to evaluate efficacy of the pasteurizer. Counts above the 20,000 cfu/ml level indicate problems with the pasteurizer which need to be addressed such

as inadequate temperature or holding time. This may be due to improper programming of the pasteurizer or inadequate hot water supply or clogged plates in the HTST units.

- A sample after the last calf is fed will help evaluate sanitation of bottles, buckets, or tanks used to hold or transfer milk to calves. Expect some increase in SPC, but it should remain less than 50,000 cfu/ml. Herds using buckets can expect higher SPC in this sample as feeding typically takes longer than in operations using bottles to feed calves.
- Alkaline phosphatase is an enzyme present in raw milk which is destroyed when the proper temperature/time ratio was achieved during pasteurization. This value should be less than 500mU/ml. However, it's been the author's experience that samples with a low value can have SPC exceeding 20,000 cfu/ml.
- Expect costs for these tests to be
  - $5 - $10/sample for SPC
  - $7.50 - $10/sample for Alkaline Phosphatase
  - $2.50 - $5.00/sample for fat, protein, lactose and total solids.

Managing nutrient content and supply variations of waste milk

Variation in nutrient content and supply of waste milk is a significant challenge of the waste milk-based calf feeding program. Problems with nutrient content are related to the following issues.

- Addition of flush water. After the end of milking it's customary to flush the lines with water. The initial milk is similar to whole milk. However, if employees are not careful, significant quantities of flush water can enter the receiving tank resulting in milk with solids less than 12.5%.
- Agitation.
  - When milk is not agitated prior to pasteurization, expect the first milk to be lower in fat than the last processed. This can be a problem when milk is directly added to bottles from the pasteurizer.
  - After pasteurization milk should be agitated prior to filling buckets. Delays longer than one hour can result in calves fed at the end of the feeding schedule receiving milk with significantly higher fat than those fed initially and vice versa.

Waste milk supply. Many descriptions of waste milk feeding programs make the assumption that adequate supplies for waste milk are consistently available. Abundant supplies of waste milk could be indicative of a failure in mastitis and herd health control programs which allow such abundant supplies of treated milk. Blosser (1979) noted that the average herd produced between 48 and 136 lb. of waste milk / cow / year. Scott (2006) found that between 5 and 22 lb. of non-saleable milk / calf / day was produced on three North Carolina and 9 California dairy herds. How does this compare to needs for the calf feeding operation? Waste milk needs are dependent on calf feeding strategies of the farm which include weaning age, and feeding rate. These relationships are shown in Table 2.

Table 2 Amount of milk required per calf as influenced by feeding rate and age at weaning.

Feeding Rate		Age at Weaning.			
Amt. Quarts	Amount (lb)	6 wk	8 wk	10 wk	12 wk
		Total milk required (lb)			
4	8.6	361	482	602	722
6	13	546	728	910	1092

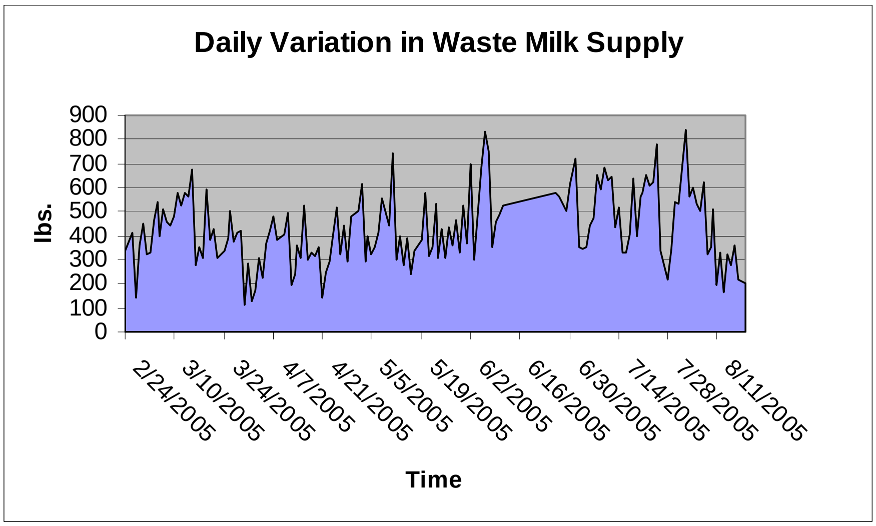
Table 3. demonstrates how many cows with discard milk at two different levels of average production would be required to meet the waste milk needs for different numbers of calves.

Table 3. Number of cows to produce waste milk required for given number of calves.

		Number of calves fed/day			
		25	50	75	100
Feed rate	Waste milk/cow/day				
4 qts.	40 lb.	6	11	16	22
4 qts.	60 lb.	4	7	11	14
6 qts.	40 lb.	8	16	24	32
6 qts.	60 lb.	6	11	16	22

An additional challenge in utilizing waste milk feeding programs concerns the stability of the daily supply of waste milk. Unfortunately "averages" can be deceiving. It's not uncommon to see large fluctuations in the quantity of waste milk available from day to day. This is best illustrated in Figure 1 which represents the recorded daily waste milk volume on one 1200 cow Holstein dairy in the eastern U.S. If the daily required volume of milk was 700 lb. / day there would be frequent, significant shortfalls of supply.

Figure 1. Daily variation in waste milk on a 1200 dairy in the eastern U.S.



This figure illustrates the challenge involved in supplementing an inadequate volume of waste milk for calf feeding. Several alternatives exist.

- Use additional saleable milk from the bulk tank. This is commonly used when deficiencies in waste milk supply are small. It can be an expensive option when quantities required are large.
- Supplement waste milk by adding additional solids from milk replacer, whey proteins and/or fat supplements. In some cases additional water is required as well. This option can be complicated as it requires knowledge of waste milk solids on a daily basis. Total solids can be estimated using digital refractometers which can provide the basis of recommendations of additional water and milk solids.
- If pasteurizer management is excellent, waste milk is fed to young calves with older calves receiving milk replacer.
- If pasteurizer management is less than desired, milk replacer is fed to the youngest calves with sensitive digestive systems and older calves are fed waste milk.

Scott et al. (2006) have shown that when diets contain equal amounts of energy and solids, calves can be successfully switched from waste milk to a higher solids milk replacer or vice versa with little trouble particularly if calves are older than 3 weeks of age when the switch is made. However, it's advisable to only make this change once.

Miscellaneous

Pasteurized waste milk feeding systems appear to be most successful when milk is pasteurized twice daily after each milking and just prior to feeding calves. With this system, bacteria don't have a chance to grow and milk is fresh for the calves. In situations where milk is only pasteurized once daily, it must be cooled to less than 40^0F and then re-warmed to 110^0F prior to feeding. How will this be accomplished? It frequently may be more troublesome than operating the pasteurizer twice daily.

Economics of pasteurized waste milk feeding systems.

Determining the cost of a waste milk pasteurizing system is difficult. What is the cost of waste milk? In some parts of the U.S., calf ranches pay $.25/gallon for the product and provide trucking from the farm to the calf ranch. Under this scenario the cost is about $3.00/cwt. However, for those on the home dairy is it really free or this low in cost? Several scenarios exist to estimate cost of waste milk. They include:

- The cost of production of fresh milk plus costs of operating the pasteurizer unit.
- Value of fresh milk
- Cost on the open market (as discussed previously) plus costs of operating the pasteurizer unit.
- Assume it's free.

Each scenario has its merits, but it's not realistic to expect that waste milk is free. This rationale transfers expense for calf feeding to the milking herd which bears the burden of production cost for "dumped" milk.

Scott (2006) studied the operation of waste milk pasteurizer systems on 3 North Carolina dairies and 9 California dairies and one calf ranch to determine operating costs of these systems. From these studies a spreadsheet was developed. Several assumptions were made in these spreadsheets as shown below. Shaded items are entered by the user.

Figure 2. Estimating net benefit from using pasteurizer. M.C. Scott author. 2006.

Inputs

8.6 lb.	Waste milk feeding rate
50 gallon	Batch pasteurizer limit
$2.90	Cost of Waste Milk
8.6 lb.	Milk replacer feeding rate
$50.00	Cost milk replacer (50 lb. bag)
13%	Mixed solids content

Capital Expenditures

Batch		HTST
$8,000	Purchase price	$20,000
$500	Building expense, modification, hot water heater, etc.	$1,000
$8,500	Total capital costs	$21,000
6.0%	Interest rate on capital	5.0%
6.0	Projected life of pasteurizer (yr)	5.0
10	Projected life of building improvements (yr)	10
$4.64	Daily capital costs	$13.01
$1,695	Annual payment for capital costs	$4,749

Batch	Energy costs	HTST
45	Temperature of milk (F) prior to pasteurization	45
50	Batch size (gallons)	N/A
1	#Batches/day	N/A
N/A	Capacity (gallons/hr) HTST	100
N/A	Hours run / day	1
N/A	Pasteurizer pump amps	18
N/A	Pasteurizer pump volts	220
45	Time (min) to reach 145F	N/A
$0.05	Cost/kwh	$.05
N/A	Cost of propane (gallon)	$1.15
N/A	Cost of natural gas (1000 cu. ft.)	$10.50
	Energy source	Propane
$.21	Daily energy cost	$7.34
$3	Wash up costs	$3.00
$500	Annual repairs and maintenance	$1,000
$8.00	Labor cost/hr.	$8.00
60	Extra time spent operating pasteurizer (min)	30
$8.00	Total labor cost	$4.00
$11.21	Total daily operating costs	$14.34
$15.86	Total daily cost	$25.88

Using this spreadsheet it is possible to calculate the net benefit (or loss) from using a pasteurizer. It is assumed that a batch system will be used for smaller herds and the HTST units for larger ones. Two examples are shown using prices of waste milk at $0.00/cwt and $3.00/cwt which is the price commercial calf raisers pay dairy producers for waste milk.

Advantage or (Disadvantage) of pasteurized waste milk versus milk replacer per day

# Calves	% Calves fed from waste milk 10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
5	($15.48)	($15.10)	($14.72)	($14.35)	($13.97)	($13.59)	($13.21)	($12.83)	($12.46)	($12.08)
10	($15.10)	($14.35)	($13.59)	($12.83)	($12.08)	($11.32)	($10.57)	($9.81)	($9.05)	($8.30)
15	($14.72)	($13.59)	($12.46)	($11.32)	($10.19)	($9.05)	($7.92)	($6.79)	($5.65)	($4.52)
20	($14.35)	($12.83)	($11.32)	($9.81)	($8.30)	($6.79)	($5.28)	($3.76)	($2.25)	($0.74)
30	($13.59)	($11.32)	($9.05)	($6.79)	($4.52)	($2.25)	$0.02	$2.28	$4.55	$6.82
40	($12.83)	($9.81)	($6.79)	($3.76)	($0.74)	$2.28	$5.31	$8.33	$11.35	$14.38
50	($12.08)	($8.30)	($4.52)	($0.74)	$3.04	$6.82	$10.60	$14.38	$18.16	$57.13
60	($11.32)	($6.79)	($2.25)	$2.28	$6.82	$11.35	$15.89	$20.42	$61.86	$68.94
70	($10.57)	($5.28)	$0.02	$5.31	$10.60	$15.89	$21.18	$64.22	$72.49	$80.75
80	($9.81)	($3.76)	$2.28	$8.33	$14.38	$20.42	$64.22	$73.67	$83.12	$92.57
90	($9.05)	($2.25)	$4.55	$11.35	$18.16	$61.86	$72.49	$83.12	$93.75	$104.38
100	($8.30)	($0.74)	$6.82	$14.38	$57.13	$68.94	$80.75	$92.57	$104.38	$116.19
110	($7.54)	$0.77	$9.09	$17.40	$63.04	$76.03	$89.02	$102.02	$115.01	$128.00
120	($6.79)	$2.28	$11.35	$20.42	$68.94	$83.12	$97.29	$111.47	$125.64	$139.82
130	($6.03)	$3.79	$13.62	$59.49	$74.85	$90.20	$105.56	$120.92	$136.27	$151.63
140	($5.28)	$5.31	$15.89	$64.22	$80.75	$97.29	$113.83	$130.37	$146.90	$163.44
150	($4.52)	$6.82	$18.16	$68.94	$86.66	$104.38	$122.10	$139.82	$157.53	$175.25

Example shown is for a waste milk cost of $0.00/cwt. The shaded blocks represent use of a batch system and the clear cells a HTST system. Milk replacer used when volume of waste milk is insufficient to meet requirements of calf enterprise for example above and below.

Advantage or (Disadvantage) of pasteurized waste milk versus milk replacer per day

# Calves	% Calves fed from waste milk 10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
5	($15.61)	($15.36)	($15.11)	($14.86)	($14.61)	($14.36)	($14.11)	($13.87)	($13.62)	($13.37)
10	($15.36)	($14.86)	($14.36)	($13.87)	($13.37)	($12.87)	($12.37)	($11.87)	($11.38)	($10.88)
15	($15.11)	($14.36)	($13.62)	($12.87)	($12.12)	($11.38)	($10.63)	($9.88)	($9.14)	($8.39)
20	($14.86)	($13.87)	($12.87)	($11.87)	($10.88)	($9.88)	($8.89)	($7.89)	($6.90)	($5.90)
30	($14.36)	($12.87)	($11.38)	($9.88)	($8.39)	($6.90)	($5.40)	($3.91)	($2.42)	($0.92)
40	($13.87)	($11.87)	($9.88)	($7.89)	($5.90)	($3.91)	($1.92)	$0.07	$2.07	$4.06
50	($13.37)	($10.88)	($8.39)	($5.90)	($3.41)	($0.92)	$1.57	$4.06	$6.55	$44.23
60	($12.87)	($9.88)	($6.90)	($3.91)	($0.92)	$2.07	$5.05	$8.04	$47.92	$53.46
70	($12.37)	($8.89)	($5.40)	($1.92)	$1.57	$5.05	$8.54	$49.77	$56.23	$62.69
80	($11.87)	($7.89)	($3.91)	$0.07	$4.06	$8.04	$49.77	$57.16	$64.54	$71.93
90	($11.38)	($6.90)	($2.42)	$2.07	$6.55	$47.92	$56.23	$64.54	$72.85	$81.16
100	($10.88)	($5.90)	($0.92)	$4.06	$44.23	$53.46	$62.69	$71.93	$81.16	$90.39
110	($10.38)	($4.90)	$0.57	$6.05	$48.85	$59.00	$69.16	$79.31	$89.47	$99.62
120	($9.88)	($3.91)	$2.07	$8.04	$53.46	$64.54	$75.62	$86.70	$97.78	$108.86
130	($9.38)	($2.91)	$3.56	$46.08	$58.08	$70.08	$82.08	$94.08	$106.09	$118.09
140	($8.89)	($1.92)	$5.05	$49.77	$62.69	$75.62	$88.54	$101.47	$114.39	$127.32
150	($8.39)	($0.92)	$6.55	$53.46	$67.31	$81.16	$95.01	$108.86	$122.70	$136.55

The example above uses a waste milk value of $3.00/cwt. Scenarios which use a price of $10.50 result in a significant reduction in net benefits with Batch and HTST units. It should be understood that the calculated net benefit is unique to a given set of circumstances and can vary significantly depending on costs of inputs and alternate prices for milk replacers. It's also important to make comparisons using milk replacers of nearly equal nutritional content as waste milk and vice versa.

Summary

The decision to utilize pasteurized waste milk requires careful consideration on all costs, personnel and health status of the herd. It's important to remember that the young calf has exacting nutrient requirements and reacts poorly to high levels of undesirable bacteria.

There are many well designed systems available to producers. Prior to making a decision consider the following:

- How many calves will be fed daily and what is the average and range in volume of waste milk produced per day? What's the range in calf numbers per day throughout the year?
- Calculate the total cost of the system to include installation and maintenance, modification of facilities, provision for adequate supplies of hot water for cleaning and adequate storage tanks for pre and post pasteurized milk.
- What system has the best service to fix the equipment should there be a breakdown?
- What strategy will be used to supplement waste milk if the supply is inadequate?
- What is health status of the herd? If Johne's or other diseases are present, there is risk of contaminating calves if there's a failure of the pasteurizer which is shown to occur approximately 10% of the time in most field studies.
- Do I have the personnel to manage this system correctly?
- Develop testing program to continuously monitor nutrient content and bacteriological quality of the waste milk to assure that pasteurization is achieved. Fat%, protein%, total solids and standard plate count should be evaluated weekly at the beginning and at least monthly thereafter to monitor employees and equipment function.

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