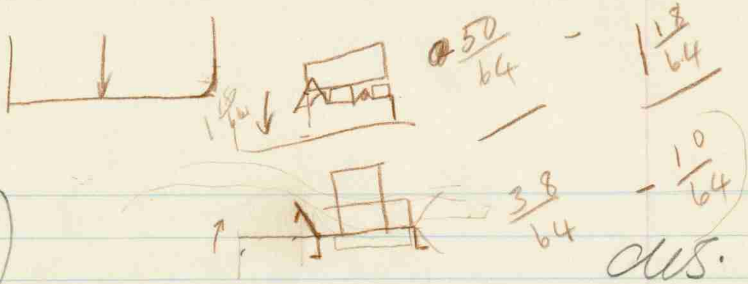


d.W.S.
March 1970

Harrington Rack

Exp. Rack

Weight 104 lb.

Welded rack

	1/4" from edge	7" from edge
Starting Height	3 45/64"	3 39/64
Loaded Height	2 59/64"	2 21/64"
Unloaded Height	3 45/64"	3 39/64"

Bolted rack

Starting Height	3 52/64"	3 25/64"
Loaded Height	3 14/64"	3 35/64"
Unloaded Height	3 52/64"	3 25/64"

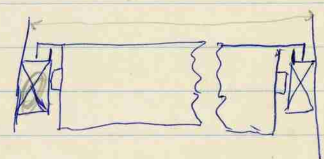
Strader Ran Tests

Rack Sizes

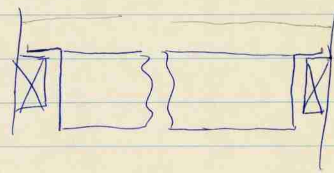
CWS - Feb 1970

Long - 55 1/4 c c of rails
52 3/4 inside clearance
56" outside overall

Harrington 55" inside clearance
58 outside overall
57 1/2 clear between rails



Powell 55 3/4 inside clearance
57 1/2 outside ~~of~~ overall
58 1/4 clear in barn above rails



Deflection of Bulk Tobacco curing rack under load
(Distances are from the floor)

Philip Davis

Harrington's new galvanized rack — Feb. 24, 1970

CleS

Old Rack

With spike attachment

Rack Unloaded	Rack Loaded	Deflection
$3\frac{11}{16}$"	$3\frac{1}{2}$"	$\frac{3}{16}$"

without spike assembly

Rack Unloaded	Rack Loaded	Deflection
$3\frac{21}{32}$"	$3\frac{7}{16}$"	$\frac{7}{32}$"

Load ≅ 46.85 Kg evenly distributed

New Rack

without spike assembly

Before loading $3\frac{2}{32}$ in → $3\frac{1}{16}$

after loading $2\frac{22}{32}$ → $2\frac{11}{16}$

$\frac{3}{8}$" deflection

Load ≅ 48 Kg. evenly distributed

Some Consideration Pertinent To
Bale Dimensions for Bulk Curing of Tobacco

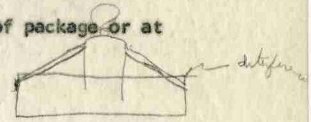
A Human Engineering Analysis

C. W. Suggs

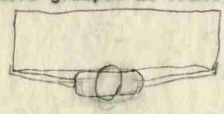
Length

Maximum length such that handles at each end could be gripped is 4'-6"-8"

This assumes that handles are at top edge of package or at least that corners of package does not interfere with arms. That is material in upper corners must be deflectable.



If package were grasped at front corners span would be about 3" longer that is



Weight

Center of gravity of package 14" thick will be 7" in front of subject. Cantilever effects of weight must be balanced by body weight and lever arm. Equation from Whitney (Ergonomics 1(2): 101-128) is applicable to this situation.

$$\text{Max. Load} = \frac{W\sigma}{p + h \tan \theta - B}$$

where W = body weight, Kg.

p = distance between balls of feet and centerline of weight, cm.

h = grasp height, cm.

θ = Angle between vertical and plane of arms

B = Constant

σ = body lever arm (for weight)

Average value of the product Wσ is ~~1978~~ 1471 Kg. cm.

Average value of B is 17.5 cm.

The value of θ will depend on package size but ~~can be approximated from drawings.~~ will be approximately 14.6° for most ~~situations~~. racks of tob.

Tan θ = ~~7/12 ≈ .6~~ .26

The value of h will be about ~~95~~ 32 cm.

The value of p will be about ~~6" ≈ 15 cm.~~ 30 cm.

Substuting:

$$\text{Max. Load} = \frac{\sout{19.8}\ 1500}{15 + .6\,(95) - 17.5} \qquad \frac{1471}{30 + .26(32) - 17.5} =$$

= 28 Kg. , = 28 x 2.2 = 61.6 lbs.

Width

Packing of leaves in layers 4' deep is significant at the lower levels. Tines, even though designed for sufficient strength to support the tobacco would become too flexible for piercing the leaves. In order to keep the tine from deflecting during loading additional strength would be needed. The deflection of a cantilever beam with end loading is

$$y = \frac{Pl^3}{3EI} = \frac{Pl^3}{3E\,\pi\,d^4/64} \quad \text{where d is the diameter.}$$

In order to hold the deflection y constant as the length l increased the ratio of $\frac{l^3}{d^4}$ would be a constant; That is, $l = d^4/3$.

An alternative would be to provide a supporting device in the loading unit.

Rack Cost

Rack cost per unit of capacity should be a minimun consistent with other design characteristics.

As rack becomes wider per unit cost of side rails and fabrication would decrease. Per unit cost of tines would increase because of need for larger dia. tines. The expression for the deflection of a simple beam with uniform loading is

$$y = \frac{5Wl^3}{384EI} = \frac{5Wl^3}{384E\,bd^3/12}$$

b = beam breadth
d = beam depth

If we assume that the allowable deflection y is proportional to the span, then y = R. l. The weight on the side bars is proportional to l and width w, that is $W = R_2\,lw$

Substituting we have

$$R.\,l = \frac{5R_2\,l\,l^3\,w}{384\,E\,bd^3/12}$$

Now E is a constant of the beam material. Assume that the breadth b is constant. Collect constants and call them K_o

$$K_o = \frac{l^3 w}{d^3}$$

and $d_s = K_1 l \sqrt[3]{w}$. Presumably the cost of the side bars will be proportional to d.

Tine size will depend on the width but not on the length. It can be shown to be $d_{tine} = K_2 W$.

Now assume that the cost of fabricating will be independent of the width and proportional to the length, F, l, Plus a constant $\underline{F}$ related to the latch mechanism on each end. Then the cost per rack is

$$C_r = F + F.l + M_s l \sqrt[3]{w} + M_t w.$$

Where M_s and M_t are constants of proper size to make the terms in which they appear become cost values consistent with the other terms. Cost per rack is not the final value of interest. The cost per unit of capacity C_u, is the value desired

$$C_u = C_{r/Lw} = \frac{F}{Lw} + \frac{F}{w}l + \frac{M_s}{w} w^{1/3} + \frac{M_t}{L}$$

This equation clearly has no minimum but decreases as either or both L and w increase.

Method of Handling

If racks are to be handled mechanically weight, length and width will not be important directly. However it should be remembered that an alternate method of handling should be available (e. g. manual) in case of mechanical failure (e. g. should one rack jump off the track).

Row width

The effect of row width on rack length could be significant. Conventional rows are 3-1/2' wide. A single skipped row will admit a

vehicle about 5' wide, that is 7 feet less 1 foot plant clearance each side. If racks are to be carried crosswise in a skip row they should not be longer than 5'.

Harvester size.

Concievably harvesters will be of two types

(1) Tractor mounted, (2) self-propelled, high clearance. The first type would be mounted on a light (one or two row) tractor. In this case bale weight should not surpass the capacity of the tractor. Implement weights for this size tractor are about 700 lbs. If the baling platform and the operator weight 400 lb. then a bale weight of 100 pounds would be acceptable, assuming that weight of the empty racks would be about 200 lb. The high clearance machine would be somewhat larger and would probably accommodate a heavier rack.

Forcing tines through leaves.

Resistance of tobacco leaves to tines will consist of two parts; (1) point resistance (puncture) (2) friction of leaves along tine. The first of these two components is independent of the thickness of the bulk. The second at any tine would be proportional to the thickness pierced. That is resistance R would be related to thickness t by $R = C_1 + C_2 t$ where C_1 and C_2 are constants. At some thickness R would become large enough to cause the tine to fail in compression.

Curing Characteristics

Bale height could have an effect on curing. Bale width (thickness) would be of importance only to the extent that nonuniform packing might take place.

Adaptability of conventional barns.

Conventional barns have at least one dimension divisible by 4 feet. The implication as to bale length is obvious.

References

McCormick, Human Engineering

Lifting - seated - atm at 90°

5th percentile is 17 & 20 lb. L & R

Mean is 52 & 56 lb. L & R

at 120° 5th percentile is 17 & 24 L & R

Mean 54 & 60 L & R

Force exerted varies with height above shoulder.

Max. force for push varied from 190 to 130 to 110 to 150 at height above the shoulder of -30, -18, 0 and +18 inches.

Woodson, Human Eng. Guide - pg. 4 - 28

Biceps strength is about 60 lb. each in lifting.

Whitney, Ergonomics, 1958 1, 2:102-128

Found max. lifting values of 41 to 64 Kg. for 8 subjects.

Values for lifting objects from 12.5 to 50 cm above the floor.

__Length__

Woodson - pg. 4 - 17

Arm span is	Low 60.6	Median 70.5	High 79.5
Arm length		30.9	
Forward reach	29.5	34.8	39.0
Fore arm length		10.6	
Span Akimbo	31.1	36.5	4.7
Hand length	6.3	7.5	8.7

Reach for C. W. Suggs in horizontal plane 12" below shoulders is 5' 10".

September 17, 1969

Dr. Harold Lewis
National Institute for Medicine Research
Hamstead Laboratories
Holly Hill
London NW3
ENGLAND

Dear Dr. Lewis:

Mr. Jan-Erik Hansson, visiting professor in this department, of the Swedish Institute of Industrial Health suggested that you have done some research on lifting and that you might have some publications of this work. If you could supply me with reprints of any such articles I would appreciate receiving copies.

This request is prompted by some rather large differences between our observations and the lifting ability suggested by Damon in "The Human Body in Equipment Design", page 321. He lists a lifting force of 36 pounds 5 feet from the floor, fifth percentile men. We have observed farm workmen routinely lifting 65 pounds to this level. Perhaps your work would allow us to estimate how badly overloaded the workmen are.

Yours very truly,

Charles W. Suggs
Professor

CWS/br

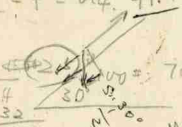
$71.0 = 80 \times \frac{\sqrt{2}}{2} + 80 \times \frac{\sqrt{2}}{2} \times f$

$\frac{14.4}{56.6} = f = 0.4$

79.4

89.8
-70.7
18.9

0.3 b



566 | 14.4
1132
3080

707 | 18.9
14
4760
Moving 4242

$79.4 = 50 + f.$

34.2
86 | 294
258
360
344
16

$f = 29.4 = N \times$ co. of $f \frac{\sqrt{3}}{2}$

100

1.72

co. of $f = 29.4/86$

86
68.8

30.8

$60.8 = 40 + f$

688 | 2080
2064
1600

$f = 20.8 = N \times$ co. of f

co. of $f = 208/688$

25

Telectrode® Application Instructions

Clinical experience has shown the following application procedure to work consistently:

Using the tip of the Telectrode paste dispenser or a cotton tip applicator, apply a small amount of Telectrode Paste to an area of skin about the size of a pea. Rub into the skin with a brisk rotary motion. About 30 rotations proved satisfactory. The skin must be stretched tightly between the thumb and index finger during this preparation in order to facilitate application.

Apply a generous amount of Telectrode Paste to the mesh area of the Telectrode. For optimum contact there should be sufficient paste to keep the pad moist but not enough to cause it to leak around the sides of the adhesive area and prevent tight contact with the skin.

Place Telectrode on previously prepared area and remove protective paper one side at a time. Peel the paper off carefully making certain that the upper corner of the Telectrode adheres firmly. Continuous adhesion will be assured if the paper is peeled from top to bottom in a rotary fashion.

Patented Form No. 3-411-10

TELEMEDICS the medical group

UA

VECTOR DIVISION OF UNITED AIRCRAFT CORPORATION

SOUTHAMPTON, PENNSYLVANIA 215 EL 7-7600

	80# bale		100# bale		100# bale
30°	58	30°	79	30°	82
	62		79		79
	58		80		81
	64		81		81
	62		78		81
av.	60.8	av.	79.4		80.8
45°	74	45°	90	45°	94
	72		88		92
	69		86		96
	69		92		94
	71		92		96
av.	71.0	av.	89.6	ave.	94.4

Ref. Roo Te

National Institute for Medical Research,
(Hampstead Laboratories),
Holly Hill, London, N.W.3.

(Human Biomechanics Laboratory)

* is only possible if such counterbalance is

19th June, 1968.

Dear Professor Suggs,

I must apoligise for not replying earlier to your letter, due to an oversight and the fact that I have been working away from my laboratory.

You raise an interesting point which was not really covered by my experiments. These were really designed to eliminate as far as possible limits on the lifting action which might be imposed by shoulder strength. You will appreciate, of course, that with the open-chain linkage situation presented by all lifting actions, the prediction of the end effects from body-weight counterbalances * the limiting factor. Even in my experiments it was not clear that at short foot-placement distance the body-weight counterbalance was more than adequate for the muscular extension forces which could be exerted at knee and hip, so that the observed lifting forces tended to be less than indicated by theory.

With lift above 50 cm., arm and shoulder action is needed in addition to knee and hip extension, and it is likely that, under many circumstances, the lifting capacity will be a reflection of arm and shoulder strength.

There is, as you may know, practical data on lifting capacity:-

<u>Emanuel & Chaffee</u> (1956): Wright Air Development Centre Technical Report 56-367.

<u>Morrissette</u> (1962): Wright-Patterson Air Force Base, Ohio. Technical Documentary Report MRL.TDR-62-57.

This, and other available information, is quite nicely summarized in <u>Damon et al</u> (1966) "Human Body in Equipment Design" (Harvard University Press), p. 320.

I hope these comments will be of use, and again my apologies for not writing earlier.

Yours sincerely,

(R. J. Whitney)

Professor C. W. Suggs,
Dept. of Biological & Agricultural Engng.,
School of Agriculture & Life Sciences,
North Carolina State University, <u>Raleigh.</u>

To open cut here

Sender's name and address: R. J. Whitney,
N.I.M.R. (Hampstead Laboratories)
Holly Hill,
London, N.W.3.

AN AIR LETTER SHOULD NOT CONTAIN ANY ENCLOSURE; IF IT DOES IT WILL BE SURCHARGED OR SENT BY ORDINARY MAIL.

The 'APSLEY' Air Letter

A John Dickinson Product

Form approved by Postmaster General No.—71995/1Z

Second fold here

First fold here

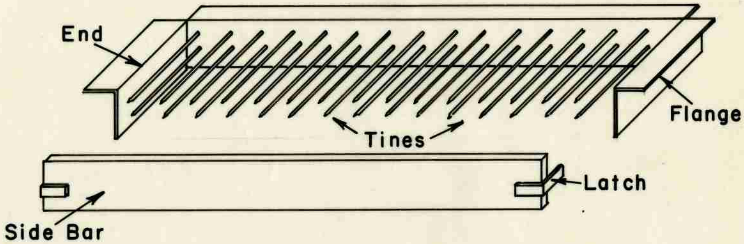
BY AIR MAIL
PAR AVION
AIR LETTER
AEROGRAMME

LONDON
19 VI 68
N.W.3.

GREAT BRITAIN POSTAGE
1/6
UH ER 681

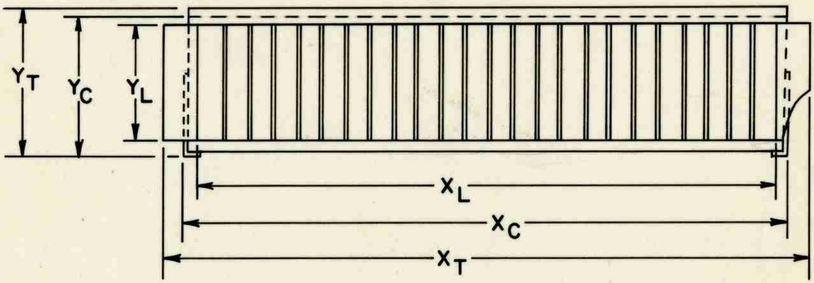
Professor C. W. Suggs,
Dept. of Biological & Agricultural Engng.,
School of Agriculture & Life Sciences,
Box 5906, Zip 27607,
NORTH CAROLINA STATE UNIVERSITY,
RALEIGH, U.S.A.

BULK CURING RACK



Pictorial

Top View



DIMENSIONS RECOMMENDED ~~BY~~ TO ASAE

X_L = OPTIONAL

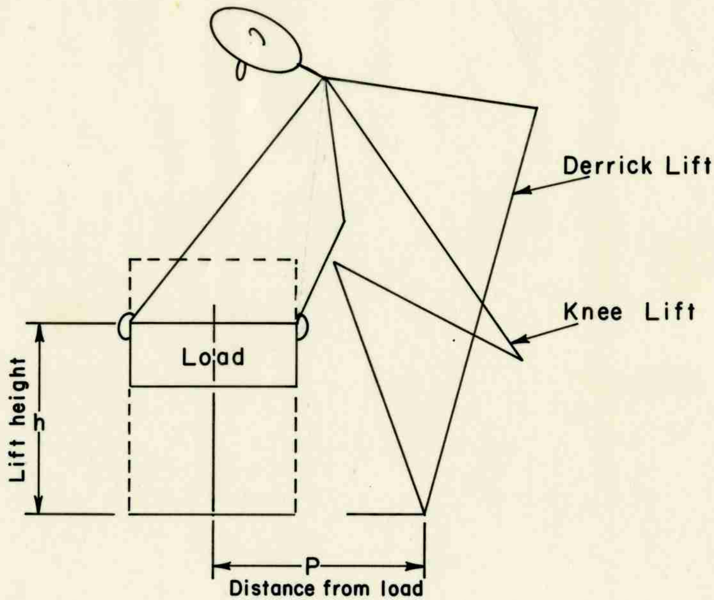
X_C = LESS THAN $55\frac{3}{4}$"

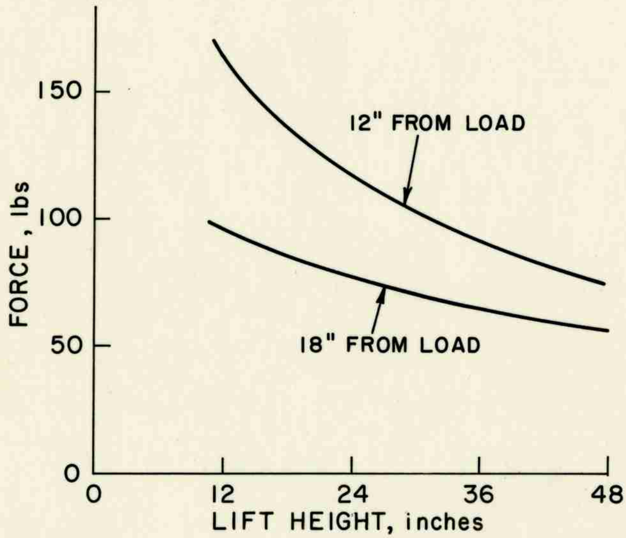
X_T = 57" ± 1"

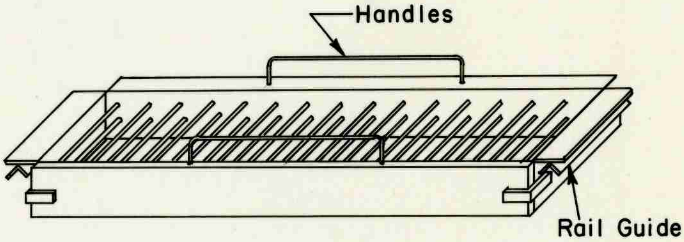
Y_L = OPTIONAL

Y_C = $15\frac{1}{2}$" ± $\frac{1}{8}$"

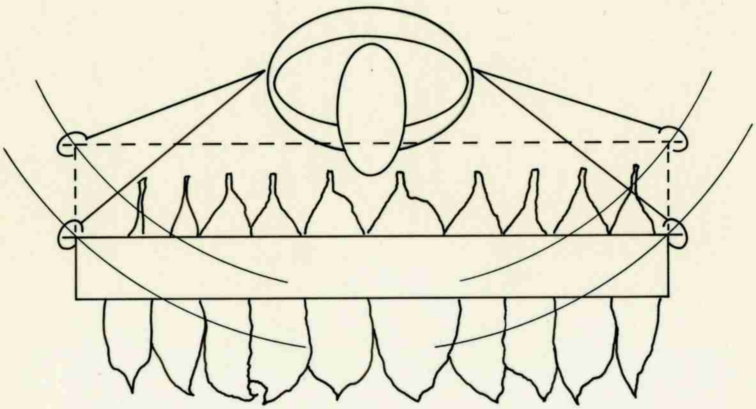
Y_T = $16\frac{1}{4}$" + 0" − 1"


Derrick Lift
Knee Lift
Load
Lift height
h
P
Distance from load


FORCE, lbs
150
100
50
0
12" FROM LOAD
18" FROM LOAD
0
12
24
36
48
LIFT HEIGHT, inches



Handles
Rail Guide



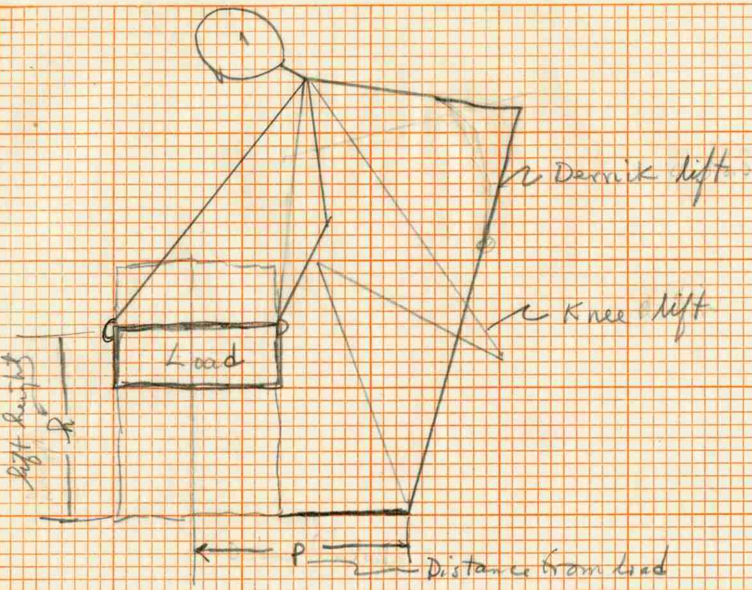


Figure 1 — Types of lifting action

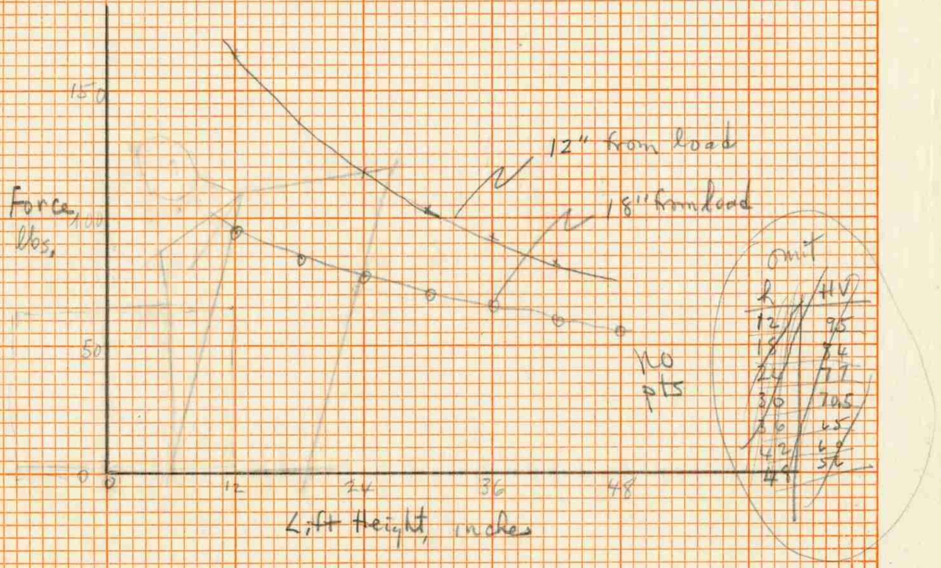
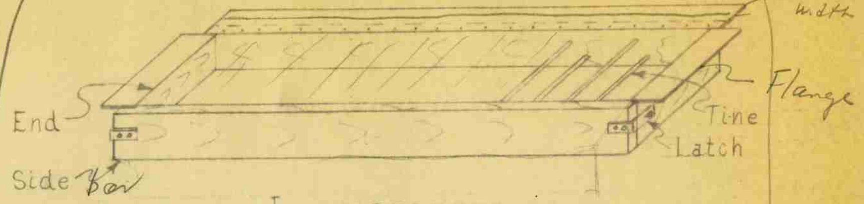


Figure 14

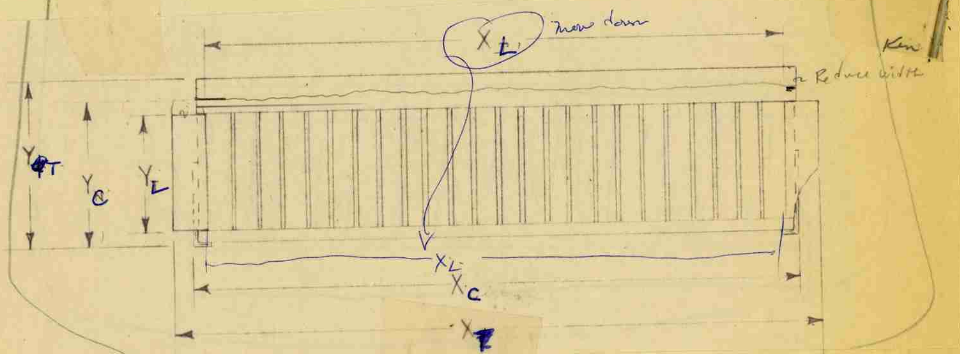
Fig 3

BULK CURING RACK



ISOMETRIC

~~RECOMMENDED NOMENCLATURE~~



TOP VIEW

Dimensions Recommended by ASAE

X_L = optional

X_C = less than $55\frac{3}{4}$"

X_T = $57" \pm 1"$

Y_L = optional

Y_C = $15\frac{1}{2}" \pm \frac{1}{8}"$ ✓

✓ Y_T = $16\frac{1}{4}" + 0" - 1"$ ✓

MANUAL HANDLING OF BULK RACKS OF TOBACCO

C. W. Suggs
Dept. of Biological and Agricultural Engineering
North Carolina State University
Raleigh, N. C.

The introduction of bulk curing techniques necessitates the substitution of a metal rack of densely packed leaves for the conventional wooden sticks onto which leaves are strung or stitched in a relative loose manner. The stick system evolved over a period of many years into a technique which was well integrated with the overall harvesting-curing-storage-marketing system. Sticks and barns were standardized over the entire U. S. flue cured area so that sticks from one farm could be loaded into a barn on another farm. Many of the handling operations were also standardized. Because this sytem evolved, optimum design was approached by successively selecting the operations which appeared to be most efficient.

Evolutionary optimization, while effective is not particularly efficient in time, capital and manpower. It is hoped that the necessary design information can be assembled so that the optimization of handling techniques for bulk bales can be approached by means of a realistic rationale rather than by evolunationary trial and error.

In a complex interdependent system it is seldom possible to substitute a new component for an old one without seriously affecting other components in the system. Bulk curing is a case in point in which substitution of bulk racks for sticks affects the barning, curing, storage and handling operations.

Paper number ____________ of the Journal Series of the North Carolina State University Agricultural Experiment Station, Raleigh, N. C.

It is the objective of this paper to assemble from the authors research and from the literature, information related to the handling of racks of tobacco in a bulk curing operation and to develop a rationale for the design of bulk racks and handling techniques.

Mechanical handling of bales by means of various types of hoists has been proposed and tried. These, in general, have proved to be too expensive and/or too time consuming to be practical. Manual handling, especially of the uncured racked leaf, because of the weight, is extremely hard drudgerous work which usually requires at least two workmen.

There are several factors related to ease of handling which should be taken into account in the design of racks and bulk curing systems. The most important among these are rack length, width, filled weight, location and design of handles and latches, and the method of alignment of the two sections during closure. Of importance in barn design are height of rails, guidance of racks on the rails, loading ramps and downwardly angled rail extensions. The last two of these are important because they can significantly reduce the effective lift height.

Lifting Force Prediction

Because the maximum weight which can be lifted by a given percentage of the population is of importance in rack design and handling some attention to lifting theory will be worthwhile. Whitney (1958) gives the following equation for predicting the maximum load in kilograms which a man can lift:

$$\text{Load} = W\alpha/p + h \tan\theta - B$$

where W = body weight, Kg.

p = distances between heels and centerline of load, cm.

h = grasp height, cm.

θ = angle between vertical and plane of arms (average value = 14.60)

α = body lever arm with respect to weight, cm.

B = constant = 17.5 cm.

Since grasp height, h, occurs in the denominator of the equation it is evident that the lifting force will decrease as the load is raised. However, because it is multiplied by Tan θ ≅ 0.26 it has less effect on the lifting force p, than the distance between load and the heels of the subject. The contribution of these two factors to the lifting equation is important where some choice of lift height and distance between load center and subject is possible.

A representative value for the product Wα has been found to be 1493 Kg cm while B is 17.9 cm. The appropriate value of p is the distance from the heels to the center of the rack of tobacco or about 45 cm for existing racks. Substituting these values into the equation simplifying and converting to pounds one has for the vertical lifting force in terms of h, the lifting height:

$$\text{Load (lbs)} = 3292/27.1 + 0.26\ h.$$

From this equation and figure 1 it can be seen that lifting force decreases appreciably as the lift height increases. If the subject can get closer to the load (smaller value of h) the lifting force is increased as illustrated by the upper curve in the figure where the value of p, the foot placement is 30 cm (about 12 inches). The figure illustrates two lifting techniques, derrick or back lift and knee lift. Whitney (1958) did not find significant differences in the forces developed by these two methods. However, the knee lift is favored because it protects the back.

Since the values shown are average maximum lifting forces, design weight should be reduced somewhat so that a higher percentage of the population would be able to lift the bale. It should also be pointed out that the values given are maximum values and would be too large for routine repetitive handling of bales.

Rack Handling and Loading Study

Methods and Materials

Present design of at least two commercial harvesters requires that one man force the rack tines through the leaves, apply enough vertical force to latch the rack, then lift the filled rack, pivot 180° and place the rack on a set of rails in a towed trailer or lay the rack on its side on a rear platform pallet. All commercial barns require lifting the rack onto one of two sets of rails set approximately three ft and five ft above the ground. This operation is usually performed using two men.

Where racking is done manually at the curing barn, two men load a racking form by hand, force the rack tines through the leaves, lift the rack, pivot 90° and place the rack on the rails in the barn.

In a normal day's operation one crew may fill as many as two barns, which may amount to approximately 12 tons of material to be transported by hand at each step of the operation requiring movement of the rack.

As a guide to standardization of rack size it was desirable to measure the response of subjects to lifting different size and weight racks in order to determine limits and investigate the existence of an optimum. Accordingly a study was set up for the purpose of determining the effects of rack load, rack width, lift height and loading aids on the physical effort required to place the racks in a curing structure.

For the tests two men in their early twenties served as subjects. Because heart rate is a measure of subject effort it was measured for each subject prior to and during the performance of the task with a pocket sized radio transmitter having electrodes taped to the chest to obtain heart-rate signals. The signal was recorded on a strip chart from a receiver located nearby.

A telescoping rack was constructed to allow testing of rack widths of 3, 4, 4 1/2, 5 and 6 feet. An adjustable frame was used to simulate a bulk barn having rail heights adjustable from 2 1/2 to 6 feet at 6 inch intervals. Burlap was used to simulate leaves in the rack and weights (rack plus burlap) were 50, 80, 100, 120 and 140 pounds.

To harvest two, 98 rack barns in one day would require the handling of approximately 20 racks per hour. However the work rate may be higher at times of loading the barn from trailers or other transport means where racking is done in the field. Therefore a loading rate of one rack every 1/2 minute was used for most of the runs except for the more severe conditions where it was extended to one rack every 40 seconds. Each subject lifted the rack from the ground, carried it 10 feet to the "barn", placed it on the rails and pushed it beyond a mark 15 inches beyond the loading point.

Ten replications were made. The racks were handled singly by each subject and as a team of two.

Results

Two measures of response were available. One of these was the heart rate approached by the subjects during the operation, Table 1. The other was the maximum height to which the load could be lifted. This information is given in Table 1 by the presence or absence of heart rate data. An

Table 1. Average heart rate for loading bulk racks

Length of rack (ft)	Height of lift (ft)	One Man Handling Weight of Rack (lbs) 50	80	100	120	Two Man Handling Weight of Rack (lbs) 80	100	120	140
3	2 1/2	97.3	102.2	108.1			99.7		
	3	95.8	100.0	120.8			101.4		
	3 1/2	94.0	102.8	117.7			96.9		
	4	98.0	108.8	131.7			101.8		
	4 1/2	102.0	112.6	120.3			101.8		
	5	104.8	*				102.2		
	5 1/2	98.9					101.5		
	6	103.7					109.7		
	Av.	99.3	105.3	119.7			101.8		
4	2 1/2		115.2	111.0	112.4	91.4	97.7	95.8	
	3		115.2	121.2		97.2	93.3	95.3	
	3 1/2		112.7	117.4		93.8	98.4	99.8	
	4		112.4	114.0		97.8	97.4	98.4	
	4 1/2		129.6	136.0		93.6	99.5	96.2	
	5		124.8			97.8	98.7	98.3	
	5 1/2					96.0	100.4	98.4	
	6					98.2	99.2	104.2	
	Av.		118.3	119.9	112.4	95.7	98.0	98.3	
4 1/2	2 1/2		138.5	108.1	120.3	96.6	103.2	103.9	
	3		127.2	112.4	125.5	98.8	105.2	117.3	
	3 1/2		122.2	121.0	128.6	98.0	106.4	118.5	
	4		130.7	124.8		96.0	109.2	111.2	
	4 1/2		151.4			99.0	107.8	115.4	
	5					100.2	104.4	126.5	
	5 1/2					100.8	107.8	109.1	
	6					100.8	111.1	112.3	
	Av.		134.0	116.6	124.8	98.7	106.9	114.3	
5	2 1/2		108.0	105.2	114.2	89.6	88.8	106.0	
	3		109.8	109.2	115.8	92.4	91.8	105.4	
	3 1/2		111.6	112.4	121.8	93.4	92.0	103.2	
	4		119.1	124.8	127.6	96.2	94.2	101.4	
	4 1/2		117.2	134.7		93.6	91.0	109.6	
	5		120.0			96.8	95.3	107.2	
	5 1/2		125.2			96.8	95.2	106.5	
	6					100.6	99.2	111.0	
	Av.		115.8	117.2	119.8	94.9	93.4	106.3	
6	2 1/2			115.6	121.2		95.7	96.7	99.4
	3			114.8	128.8		96.4	100.8	103.7
	3 1/2			115.0	133.9		96.6	99.8	101.2
	4			124.4	140.2		95.8	105.0	102.5
	4 1/2			120.1	141.5		96.0	103.0	103.7
	5						100.8	105.0	111.1
	5 1/2						97.9	101.0	106.8
	6						99.8	109.2	113.5
	Av.			117.9	133.1		97.4	102.6	105.2

* Missing data indicates that subject could not complete test sequence at the higher levels.

analysis of variance of the heart rate response to the lifting and loading operation showed that there were significant differences with respect to subjects, lift heights and weight. Rack length in the range tested did not significantly affect the operation.

The average person can sustain a work load causing a heart rate of 110 beats per minute on a continuing basis. Rates above this cause excessive fatigue and degradation of performance.

Weight and height of lift

With the exception of the sequence at 50 pounds rack weight all of the run sequences for single man loading are incomplete due to physical inability of the men to hoist the rack to the desired height. An 80 pound sequence was not included for the 6 foot rack length as it was felt this would be unrealistically light, and a 120 pound sequence was omitted for the 3 foot rack as being unrealistically heavy for the length.

The run with the 4 1/2 foot rack at 80 pounds load was one of the first runs and reflects the lack of conditioning on the part of the subjects.

In general there was the expected increase in heart rate with load and with height of lift. From the results of these tests it would appear that one man should not be required to continuously load 80 pound racks over 4 feet or 100 pound racks over 3 feet at the rate of one every 1/2 minute. All heart rates for the 120 pound load were above 110 beats per minute.

In the two man loading operation rack weights up to 140 pounds could be lifted up to 6 feet without exceeding the allowable work load limit. One run using the 4 1/2 foot racks at 120 pounds gave an average heart rate of 114.3 pounds but this probably reflects conditioning at the time of the test since 5 foot and 6 foot racks could be handled satisfactorily at this load.

Rail extensions

The addition of rail extensions 2 1/2 feet long extending downward at about 45° made it possible for one man to load racks to heights of 6 feet. Table 2 shows the average heart rate for 80, 100, and 120 pound racks when rail extensions were used. Only the 6 foot lift required excessive effort for the 80 pound racks but all 100 and 120 pound lifts were excessive at all lifting heights.

Use of ramp

The average heart rate for tests utilizing a 1 1/2 foot high ramp on which the subject stood to reach the rail also made it possible for one man to lift racks up to 6 feet above the ground. However, effort requirements were excessive for lifts of 80 pounds above 5 1/2 feet and for all 100 and 120 pound lifts.

Rail guides

A V-rail was also tried. As shown in Table 2 it did not enable the filling of rail positions above 5 feet at 80 pounds lift and above 4 feet for 100 pound lifts. The V-rail did eliminate much of the skewing and jamming of the racks which was encountered with flat rack flanges.

The results of this study clearly show that one-man handling of racks is limited to the handling of lighter rack weights and to lifts not exceeding 4 1/2 feet. Rack weights of 120 pounds are difficult to handle and would tend to tire the average worker rapidly.

Two-man handling of racks was satisfactory up to 140 pounds and for lift heights up to 6 feet.

There was no clear indication of an optimum length of rack for either one man or two man handling.

Table 2. Average heart rate comparing lift aids (five foot rack length - one man)

Method	Lift Height (ft)	Rack Weight (lbs) 80	100	120
Rail extension	4 1/2	106.2	114.2	124.4
	5	110.2	119.4	130.8
	5 1/2	109.0	126.2	131.6
	6	114.7	137.0	142.1
	Average	110.0	124.2	132.2
1 1/2 foot ramp	4 1/2	106.0	115.8	120.4
	5	107.6	120.6	125.5
	5 1/2	112.2	124.5	135.0
	6	115.4	134.2	
	Average	110.3	123.7	126.9
V-rail	2 1/2	97.3	115.8	
	3	101.0	119.0	
	3 1/2	102.4	126.3	did
	4	106.0	136.2	not
	4 1/2	105.8		run
	5	114.4		
	5 1/2			
	6			
	Average	103.6	124.3	

Rack Length

Since lifting and loading results did not exhibit any significant effects of rack length it is necessary to consider other criteria. One such possible criterion is the limitation imposed on the unlatching operation by arm span. In existing racks the latches which lock the rack in the closed position are realistically located on the extreme ends of the rack. It is desirable, and in some cases almost necessary to depress both latches simultaneously in order to unlock and remove the cured tobacco. Thus arm span should equal or exceed rack length.

Figure 2 illustrates the 5th and 95th percentile man in relationship to a rack 56 1/4 inches* long which is the length being tentatively recommended by the American Society of Agricultural Engineers. As can be seen from the figure the 95th percentile man can easily span the length of the rack. The 5th percentile man would have to stand close to the rack in order to span its length as indicated by the dotted line. This would require him to lean forward to prevent interference between his body and the tobacco loaded in the rack.

Rack width

Other factors being constant, rack width determined the weight of the loaded rack. A width of about 15 inches coupled with a length of about 56 inches (both recommended values) determines a rack which will weigh about 115 pounds when filled to a reasonable density with normal size tobacco. Reference to tables 1 and 2 indicates that one man could not lift racks of this weight

*Other tentative recommended dimensions are given in Figure 3.

onto the rails unless angled rail extensions or ramps were used. Even when such aids were used the effort was excessive at a loading rate of 1/2 minute per rack. Two men can handle this weight without excessive effort.

Depending on the individual involved it may well be that the high effort inputs could be tolerated for relatively the short period of time required to transfer a trailer or truckload of racks into the barn.

It is unlikely that narrow racks would be desirable overall because they would be more expensive per unit of capacity and would reduce barn capacity because more of the floor area would be covered by the perimeter of the racks. On the other hand larger racks three to four feet wide tend to load unevenly due to compaction of the leaf on one side of the rack. This is due primarily to a density gradient which is established when the rack is turned on its side during the filling operation.[*] If this problem could be solved, large racks could probably be handled by a fork lift or similar machinery in an efficient manner.

Rack width also determines, especially for the beginning of a lift, how close the subject can get to the center of the load. From the weights lifted and Figure 1 it is evident that the subject is closer to the load than was the case for even the better of the two curves shown. Such is actually the situation in lifting because the subject tends to stop under the load as the height increases.

Some additional length in the rail extensions or additional height in the ramp would reduce the effective lift height. This would spread out the energy input over a longer period of time thereby reducing the magnitude of the impulse type requirement.

---

[*]Splinter, W. E. and Suggs, C. W. Tobacco mechanization progress report, 1961.

Handles

The effort required for lifting, carrying and positioning of racks could be alleviated somewhat if well placed properly designed handles were available. Figure 4 shows the location which was suggested for one-man handling by the handling study. Commercial racks currently available are difficult to grasp because many of the rack edges are sharp and often partially imbedded in the tobacco. The use of gloves, with the attendant loss of feel, are required to reduce the incidence of cut hands. Also some damage to the leaves occurs because of the manner in which the leaves cover the sides of the rack. The ends of the rack are usually free of obstruction so that they can be reached when the rack is to be lifted by a man at each end. However, sharp edges are also found in these areas.

The handle location and length shown in the figure would accommodate either a right or left handed individual handling the rack alone. It is normal for a right handed person to grip the far (rear) side of rack with his right hand at a point slightly to the right of center. His left hand is placed on the front of the rack just to the left of center. The suggested length is long enough to permit a reversal of this technique for a left handed person. Some thought would allow the handles to be incorporated in the overall design of the rack so as to contribute to the structural strength of the rack. If this were done little additional cost would be incurred.

As an alternative, detachable handles which would fit into notches, grooves or holes in the rack sides could be used. In general, such devices do not work well because of the time and effort required to attach and remove them.

Alignment

Racks consist of two members, the body onto which the tines are mounted and a side bar or bottom which latches to the body to prevent the leaves from falling off the tines. Latching of the side bar to the rack body requires that these two members approach each other in the proper spatial relationship or alignment. In a normal filling operation the side bar is placed so that leaves may be loaded over it. The rack body is then pressed down, with the tines penetrating the leaves, until the side bar is engaged. In some racks alignment is insured by guide strips attached at right angles to each end of the rack side bar. These engage the ends of the rack body before the tines penetrate very deeply into the leaf mass. Other racks have no alignment means and, therefore, are dependent on a racking frame to guide the rack body into the proper position to engage the side bar. In this case alignment is not as positive and dimensional tolerances plus structural deflection of the rack and/or racking frame sometimes allow sufficient misalignment to prevent latching of the rack. This produces a management and handling problem, particularly if other operations must be synchronized with racking as on a mechanical tobacco harvester.

Summary and Conclusions

With the introduction of bulk curing of bright leaf tobacco there has originated a need for the development of a rationale to aid in the design of bulk curing racks which can be efficiently and easily handled. As a step in the development of such a rationale a study which included observations on rack width, component alignment, handles, and guides plus and in-depth investigation of the effects of rack length, weight and lift height and an analysis of lifting forces was conducted.

The results of this study indicated that weight and height of lift were the two most important factors in the handling of bulk racks. It was found that either of the subjects could lift a 50 lb bale and place it on rails 6 ft above the ground or an 80 lb bale 4 1/2 to 5 1/2 ft. A 100 lb bale could be lifted and placed at a height of 4 to 4 1/2 ft while the 120 lb bale could be lifted 3 1/2 to 4 1/2 ft.

When the two subjects handled the bale as a team all of the weights up to and including 140 lbs could be lifted to rails 6 ft above the ground which was the highest level in the study.

The values listed for the one-man lifts represent maximal efforts and hence exceed reasonable design values, which should probably be about 1/2 foot less than the smaller value just listed. Effort requirements for one-man handling as measured by the heart rate of the subjects was found to be above the level which a subject could sustain continuously. However, it could be tolerated for the relatively short period of time required to handle the racks from a trailer or small truck. Effort requirements for the two-man team were within the continuous capabilities of the subjects.

Rack length and width in the range observed did not appear to affect the ease of bale handling. However, because of the difficulty of gripping the bale without damaging ones hands or the tobacco the need for the handles became evident.

Downwardly angled rail extensions or a ramp both of which reduce the effective lift height made it possible for either subject to lift the 120 lb bale to a height of 5 1/2 or 6 ft. Effort requirements were high but could be tolerated on an intermittent basis.

From this study it can be concluded that:

1. Weight and height of lift are the most important factors in the manual handling of racks of tobacco.
2. Rack length and width have little effect on handling ease.
3. Lifting of normal weight bales (100 - 120 lb) by one man and placing on the upper rail in a bulk barn (5 - 6 ft) is beyond the capabilities of most men.
4. Devices such as angled rail extensions or ramps which reduce the effective lift height make it possible for one man to load racks into a barn.
5. Effort requirements, except for a two-man team, are sufficiently high to make intermittent activity necessary.
6. Two men working as a team can handle normal bales and place them on the upper rails without excessive effort.

Whitney, R. J. The Strength of the Lifting Action in Man. Ergonomics 1(2): 101-128, 1958

Woodson, W. E. and Conover, D. W. Human Engineering Guide for Equipment Designers. Univ. of Calif. Press. Berkeley page 5-16, 5-17

The 45-inch racks Wayne Parrish had made for his barns are a lot easier to handle.

Three Virginians In Same County Have Different Bulk Curing Systems

Three Lunenburg, Virginia, farmers who have no more than 10 acres of tobacco apiece, felt justified in going to bulk curing. To them, it was the answer to what plagued tobacco farmers everywhere last year — labor.

Staff Report

Folks in Lunenburg County point to Wayne J. Parrish of Kenbridge as the man to see about bulk curing. The young farmer has been bulk curing tobacco since 1962, when he built his own bulk curing barn out of exterior plywood and aluminum. The barn is 8 by 20 feet and holds the equivalent of 450 sticks. The farmer built another one in 1966 out of 8-inch cinder block and insulated it with vermiculite. It is 8 feet longer than the first barn and holds the equivalent of 150 more sticks.

Grain dryers and 2-foot high pressure fans are used for curing the tobacco. Without the cost of the racks and burners, Parrish says it cost him $300 to construct each barn. The direct burners cost $550 each.

When asked why he began bulk curing as early as he did, the young farmer replied, "I just thought it was the wisest thing to do. I had to replace a barn that burned, and I haven't regretted it since. It wasn't a question of how much labor I would have but whether I could get anyone to help me harvest my nine acres of tobacco." His family consists of his wife and two daughters both under seven years of age.

Smaller Bulk Racks

Parrish is pleased that he had smaller special model bulk curing racks manufactured for him by a leading tobacco equipment manufacturer. The racks are 45 inches in length and, a lot easier to handle than the conventional ones, he reports. He can put them into the barn himself.

The tobacco grower has cured at least nine barns each season in the first barn he built. "I had to learn from experience just how to get my tobacco cured properly," Parrish admits.

Eighty to 90 gallons of LP gas are required to cure a barn. Electricity costs $1 a day and it takes five days to cure a barn. The temperature of the barn is maintained 5 degrees higher than the outside temperature for the first 24 hours. The next 12 hours it is raised to 100 and then to 105 degrees until the leaves are ready to dry.

Then he increases the temperature up to 120 to 125 degrees and begins ventilating. In 4 hours the temperature is raised to 130 degrees at 40 percent ventilation and stays there for 8 hours. He then cuts back to 20 percent ventilation and raises the temperature to 140 degrees for 4 more hours. The temperature is then raised to 160 degrees. Ventilation is cut back to 10 percent and remains there until 90 percent of the stems are dead. At this stage, ventilation is cut off until all the stems are dead.

Parrish says he gets four sheets of tobacco from the older barn per cure and five sheets from the other. About 15 racks constitute a sheet of tobacco.

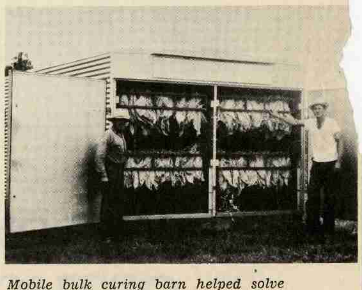
To help in his bulk curing operation, Parrish also constructed a homemade harvester. Two people prime the tobacco, which is racked on a platform on the priming aid. His six-year-old daughter drove the tractor. A furrow was made in the fifth row to steer it. Parrish loads the tobacco into the barn himself and estimates it takes 17 hours to fill 117 racks of the bottom-of-the-stalk tobacco.

Mobile Bulk Barn

Not too far from Parrish is Troy Moore, who installed a Long mobile bulk curing barn two years ago. Moore has 10 acres of tobacco and puts about half of it in the bulk barn and the other half in conventional ones. He plans to go entirely to bulk curing.

Labor was also the reason this farmer decided to go the bulk cur-

(Continued, page 26)



Mobile bulk curing barn helped solve labor problems for Troy Moore, right. His father, Jeff, left, helps him load the barn.

Some Consideration Pertinent To
Bale Dimensions for Bulk Curing of Tobacco
A Human Engineering Analysis

C. W. Suggs

Length

Max length such that handles at each end could be gripped is 4'-6"-8"

This assumes that handles are at top edge of package or at least that corners of package ~~does~~ do not interfere with arms. That is material in upper corners must be deflectable.

If package were grasped at front corners span would be about 3" longer that is

Weight

Center of gravity of package 14" thick will be 7" in front of subject. Cantilever effects of weight must be balanced by body weight and lever arm. Equation from Whitney (Ergonomics 1-2:114):

$$\text{Max. Load} = \frac{W\alpha}{p + h \tan\theta - B}$$

where W = body weight, Kg.

p = distance between balls of ~~fat~~ feet and centerline of weight, cm. 7" ≈ 18 cm

h = grasp height, cm.

θ = Angle between vertical and plane of arms

B = Constant

α = body lever arm (for weight)

Average value of the product Wα is 19.8 Kg. cm.

Average value of B is 17.5 cm.

The value of θ will depend on package size but can be approximated from drawings.

Tan θ = ~~7/12 ≈ .6~~ = .26

The value of h will be about 95 cm.

The value of p will be about 6" = 15 cm.

Substuting:

$$\text{Max. Load} = \frac{19.8}{15 + .6\,(95) - 17.5} \qquad \frac{1493}{30 + .26(h) - 17.5}$$

NOMENCLATURE AND SPECIFICATIONS FOR TOBACCO CURING SYSTEMS

Proposed by the PM-03/1 Subcommittee on Tobacco Mechanization for Consideration by ASAE PM-03 Technical Committee May 1,1968

SECTION I - PURPOSE AND SCOPE

1.1 One purpose of this recommendation is to establish standards of nomenclature and terminology related to the bulk curing process for tobacco. Since the bulk curing process is of recent development there exists a considerable amount of confusion as to the terms by which bulk curing components are described.

1.2 A second purpose is to establish uniform methods of capacity ratings of bulk curing equipment.

1.3 A third purpose is to set up dimensional criteria which will allow interchangeability of bulk curing racks for use in bulk curing structures and on mechanical harvesting equipment.

1.4 The recommendations set forth here pertain to the curing process for all types of tobacco categorized as Flue Cured Tobacco. They do not necessarily apply to Cigar, Burley or other types of tobacco.

SECTION II - NOMENCLATURE FOR TOBACCO CURING SYSTEMS

2.1 Bulk Curing Structure

2.1.1 The bulk curing structure shall consist of a number of rooms, each room having one or more sets of rails for supporting tobacco racks during the curing process.

2.1.2 Each set of rails shall comprise one tier.

2.1.3 The capacity rating of the structure shall be the number of racks contained in the curing chamber times the load area of one rack in square feet.

2.1.4 The furnace, consisting of a fan or blower, combustion unit and air proportioning system shall be rated at the Btu/hr delivered to the load area at rated air flow.

2.1.5 Rated air flow will be the cubic feet of air/min/ft^2 of floor area with 0.1 inch pressure drop per tier at standard conditions.

2.2 Bulk Curing Rack

2.2.1 The bulk curing rack is the framed member, containing one or more rows of tines, used to support the tobacco leaves during the curing process.

2.2.2 The rack is usually constructed of a tined section which latches with a second section to clamp the leaves in place for handling. In the normal loading operation the second section is placed down first, the leaves are loaded and the tines are pressed downward through the leaves until the rack latches. Therefore, the tined member shall be called the rack top and the second section the rack bottom as this is the normal configuration at time of loading.

2.2.3 The amount of tobacco which may be packed into any one rack will depend on the load area of the rack. The load area shall be defined as the inside clear length times the inside clear width of the rack neglecting the area reduction due to the presence of tines.

SECTION III - DIMENSIONAL SPECIFICATIONS FOR BULK CURING SYSTEMS

3.1 Bulk Curing Rack

3.1.1 A representative bulk curing rack is shown in Figure 1 together with significant dimensions for three current manufacturers of racks.

3.1.2 Rack capacity (see paragraph 2.2.3) is defined as X_L times Y_L.

3.1.3 Rack length X_T sets the minimum room width within which the rack may be placed and the maximum width between rails for support of the rack. Rack length is also an important dimension from the standpoint of mechanical racking. It is recommended that rack length X_T be standardized at 57" $\pm$ 1".

3.1.4 Rack width in the nested configuration Y_C determines the number of racks which can be placed in a given room length. It is recommended that rack nesting width be standardized at 15½" + 1/8".

3.1.5 Maximum rack width Y_T sets design criteria for mechanized clamps for use on mechanical harvesting equipment and at the curing structure. It is recommended that maximum rack width be standardized at 16¼" + 0", -1".

3.2 Bulk Curing Structure

3.2.1 It is recommended that bulk curing barn room width be standardized at 59" ± 1/4". Widths greater than this would be acceptable but wasteful of space. Widths less than this effectively exclude interchangeability of racks.

3.2.2 It is recommended that free clearance between barn rails be standardized at 55 3/4".

3.2.3 For a room width of 59" it is recommended that rail width be 1 5/8".

Shortest standard rack would be 57-1 = 56" - It could not be easily be suspended from rails 53 3/4" (clear) apart.

Weight

Filled ~~rack~~ weight is probably the most important single factor in the manual handling of tobacco ~~for~~ for bulk curing...

Although bales of tobacco for bulk curing will likely ultimately be handled mechanically, in the interim, there is still a need to consider bale size with respect to the capabilities of the men who will be working with them. Also it is likely that some manual handling of bales will be necessary due to malfunction of handling equipment.

Length. In order to permit a workman to manipulate the latch on each end simultaneously, guide the rack onto the barn rails and use the end plates as carrying handles it would be desirable to limit bale length. Median arm span according to Woodson (Human Engineering Guide) is 70.5 inches and hand length is 7.5 inches. Depending on location of the latches and how manipulated as well as location of members which might be used for handles a maximum bale length of from 54" to 60" should be suitable for a majority of men.

Weight. Whitney (Ergonomics 1 (2):101-128) gives an equation which predicts the maximum load which a man can bend over and lift. His equation is

$$\text{Load} = \frac{W\alpha}{p + h \tan \theta - B}$$

where W = body weight

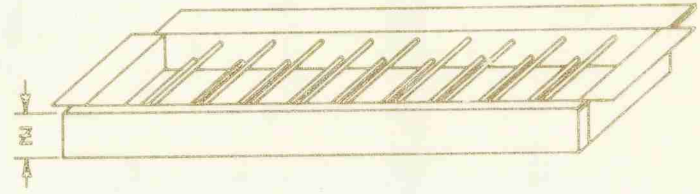
p = distance between ~~balls of feet~~ heels and centerline of weight

h = grasp height

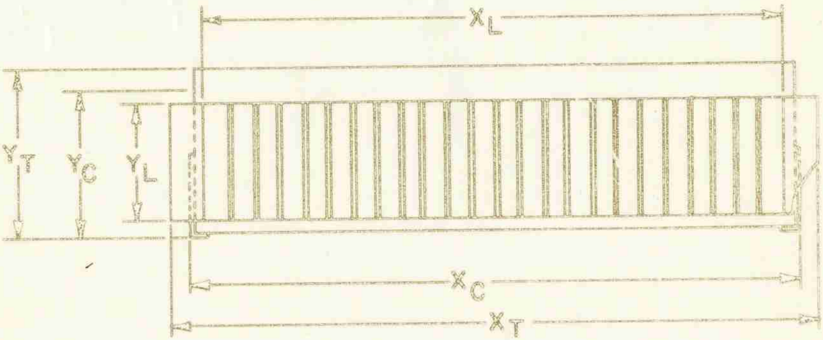
θ = angle between vertical and plane of arms (average value = 14.6°) → Tan θ = 0.26)

α = body lever arm with respect to the weight

B = constant = 17.5 cm.



TOP VIEW



Recommended		POWELL RACK	LONG RACK (1)	LONG RACK (2)	HARRINGTON RACK
57 ± 1"	X_T	57 1/2" ✓	~~58 3/8"~~	56" ✓	58 1/8" ✓
less than 55 3/4	X_C	53 7/8" ✓	56"	52 5/8" ✓	55 1/4" ✓
	X_L	53 5/8"	55"	51 5/8"	54 7/8"
16 1/4 +0 −1"	Y_T	16 1/8" ✓	15 5/8"	15 5/8" ✓	16 1/4" ✓
15 1/2 + 1/8 −	Y_C	15 3/8"	15 3/8"	15 3/8"	15 1/2"
	Y_L	13 3/4"	12 1/2"	12 1/2"	13"
	Z	5"	8 1/4"	8 1/4"	5"

59" ± 1/4" Barn

55 3/4 Free clearance between rails –

Factor Affecting the Efficient

Manual Handling of Bulk Racks of Tobacco

Considerations Pertinent to the Manual Handling of Bulk Racks of Tobacco.

✓ Length	Barn Rails	✓ Height of lift
✓ Width	Alignment of two sections	✓ Steps
✓ Weight	Latches	✓ Angle rail extensions
Handles		~~Horizontal rail extensions~~

1493
2205
7465
29860
2986
3292.065

= 28 Kg. , = 28 x 2.2 = 61.6 lbs.

Width

Packing of leaves in layers 4' deep is significant at the lower levels. Tines, even though designed for sufficient strength to support the tobacco would become too flexible for piercing the leaves. In order to keep the tine from deflecting during loading additional strength would be needed. The deflection of a cantilever beam with end loading is

$$y = \frac{Pl^3}{3EI} = \frac{Pl^3}{3E\pi d^4/64}$$ where d is the diameter.

In order to hold the deflection y constant as the length l increased the ratio of $\frac{l^3}{d^4}$ would be a constant; That is, $l = d^{4/3}$.

An alternative would be to provide a supporting device in the loading unit.

Rack Cost

Rack cost per unit of capacity should be a minimun consistent with other design characteristics.

As rack becomes wider per unit cost of side rails and fabrication would decrease. Per unit cost of tines would increase because of need for larger dia. tines. The expression for the deflection of a simple beam with uniform loading is

$$y = \frac{5Wl^3}{384EI} = \frac{5Wl^3}{384E\, bd^3/12}$$

b = beam breadth
d = beam depth

If we assume that the allowable deflection y is proportional to the span, then $y = R_1 l$. The weight on the side bars is proportional to l and width w, that is $W = R_2\, lw$

Substituting we have

$$R_1 l = \frac{5R_2 l\, l^3 w}{384\, E\, bd^3/12}$$

Now E is a constant of the beam material. Assume that the breadth b is constant. Collect constants and call them K_o

$$K_o = \frac{l^3 w}{d^3}$$

and $d_s = K_1 \, l \, \sqrt[3]{w}$. Presumably the cost of the side bars will be proportional to d.

Tine size will depend on the width but not on the length. It can be shown to be $d_{tine} = K_2 W$.

Now assume that the cost of fabricating will be independent of the width and proportional to the length, $F_1 \, l$, Plus a constant F related to the latch mechanism on each end. Then the cost per rack is

$$C_r = F + F_1 l + M_s \, l \sqrt[3]{w} + M_t \, w.$$

Where M_s and M_t are constants or proper size to make the terms in which they appear become cost values consistent with the other terms.
Cost per rack is not the final value of interest. The cost per unit of capacity C_u, is the value desired

$$C_u = C_{r/LW} = \frac{F}{LW} + \frac{F_1}{W} + \frac{M_s}{W^{2/3}} + \frac{M_t}{L}$$

This equation clearly has no minimum but decreases as either or both L and W increase.

<u>Method of Handling</u>

If racks are to be handled mechanically weight weight, length and width will not be important directly. However it should be remembered that an alternate method of handling should be available (e. g. manual) in case of mechanical failure (e. g. should one rack jump off the track).

<u>Row width</u>

The effect of row width on rack length could be significant. Conventional rows are 3-1/2' wide. A single skipped row will admit a

10 160 (300)

vehicle about 5' wide, that is 7 feet less 1 foot plant clearance each side. If racks are to be carried crosswise in a skip row they should not be longer than 5'.

Harvester size.

Concievably harvesters will be of two types

(1) Tractor mounted, (2) self-propelled, high clearance. The first type would be mounted on a light (one or two row) tractor. In this case bale weight should not surpass the capacity of the tractor. Implement weights for this size tractor are about 700 lbs. If the baling platform and the operator weight 400 lb. then a bale weight of 100 pounds would be acceptable, assuming that weight of the empty racks would be about 200 lb. The high clearance machine would be somewhat larger and would probably accomodate a heavier rack.

Forcing tines through leaves.

Resistance of tobacco leaves to tines will consist of two parts; (1) point resistance (puncture) (2) friction of leaves along tine. The first of these two components is independent of the thickness of the bulk. The second at any time would be proportional to the thickness pierced. That is resistance R would be related to thickness t by $R = C_1 + C_2 t$ where C_1 and C_2 are constants. At some thickness R would become large enough to cause the tine to fail in compression.

Curing Characteristics

Bale height could have an effect on curing. Bale width (thickness) would be of importance only to the extent that nonuniform packing might take place.

Adaptability of conventional barns.

Conventional barns have at least one dimension divisible by 4 feet. The implication as to bale length is obvious.

TOP VIEW

POWELL RACK

$X_L = 57\frac{3}{4}''$ ✓

$X_C = 54\frac{5}{8}$

$X_T = 53\frac{3}{4}$

$Y_W = 15\frac{1}{2}''$

$Y_N = 14\frac{1}{4}''$ $15\frac{1}{2}$ space in barn

$Y_T = 13\frac{1}{2}$ - Free space

$Z = 4\frac{1}{8}''$

59" wall to wall

LONG RACK

$X_L = 59\frac{1}{4}''$ ✓

$X_C = 57$ $(54\frac{1}{2})$

$X_T = 55\frac{3}{4}''$ ✓ ([illegible]'')

$Y_W = 15\frac{1}{2}''$

$Y_N = 14\frac{3}{4}$

$Y_T = 12\frac{3}{8}''$

wall to wall 61

ROANOKE RACK

$X_L = 58''$ –

$X_C = 57$

$X_T = 55''$

$Y_W = 16''$

$15\frac{1}{2}$ – [illegible]

$Y_T = 13\frac{3}{4}$

wall to Wall $61\frac{5}{16}$

Recommended

$58\frac{1}{2} \pm \frac{3}{4}$

less than 57

$15 \pm \frac{1}{2}$

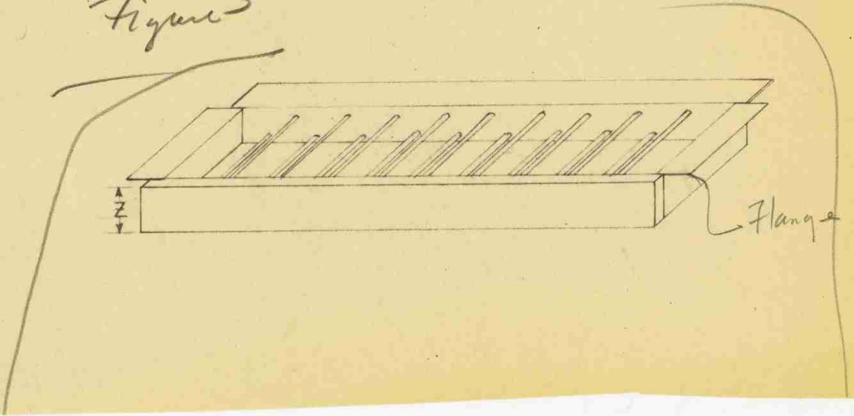
Recommendations X_L $58\frac{1}{2} \pm \frac{3}{4}''$

X_C $56\frac{1}{4}$ $+\frac{3}{4}$ $-$ any amount.

$Y_N = 15 \pm \frac{1}{2}$

Average inside dimensions of farmers base
16' outside

Figure 3



References

McCormick, Human Engineering

Lifting - seated - atm at 90°

5th percentile is 17 & 20 lb. L & R

Mean is 52 & 56 lb. L & R

at 120° 5th percentile is 17 & 24 L & R

Mean 54 & 60 L & R

Force exerted varies with height above shoulder.

Max. force for push varied from 190 to 130 to 110 to 150 at height above the shoulder of -30, -18, 0 and +18 inches.

Woodson, Human Eng. Guide - pg. 4 - 28

Biceps strength is about 60 lb. each in lifting.

Whitney, Ergonomics, 1958 1, 2:102-128

Found max. lifting values of 41 to 64 Kg. for 8 subjects.

Values for lifting objects from 12.5 to 50 cm above the floor.

Length

Woodson - pg. 4 - 17

Arm span is	Low 60.6	Median 70.5	High 79.5
Arm length		30.9	
Forward reach	29.5	34.8	39.0
Fore arm length		10.6	
Span Akimbo	31.1	36.5	4.7
Hand length	6.3	7.5	8.7

Reach for C. W. Suggs in horizontal plane 12" below shoulders is 5' 10".

Since h, the grasp height, is multiplied by Tan θ = 0.26 it has less influence on the equation than p, the foot placement. This is of importance when loads must be lifted to various heights.

A representative value for the product Wa has been found to be 1493 Kg. cm. while β is 17.9 cm. The appropriate value of p is the distance from the heel to the center of the rack of tobacco or about 45 cm. Substituting these values into the equation and simplifying one has for the vertical lifting force in terms of the lifting height:

$$HV = \frac{1493}{27.1 + 0.26h} Kg \left(2.205 \, lb/Kg\right)$$

From this equation and figure — it can be seen that lifting force decreases appreciably as the lift height increases. If the subject can get closer to the load the lifting force is increased as illustrated by the upper curve in figure — where the value of p, the foot placement, is 30 cm (about 12 inches).

Since this is the average maximum, design weight should be decreased somewhat so that a higher percentage of the population would be able to lift the bale. It should also be pointed out that this is a maximum value describing the capacity of the individual for occasional or emergency encounters, e.g., should a bale fall off the barn rails. Routine manual handling of bales of this weight would require two men.

Length

It can be shown that the rack cost per unit of capacity decreases as rack size increases. Therefore, rack size should be as large as possible consistent with ~~the~~ handling and functional limitations.

LIFTING

C. Saran 1966

Lifting of weights may cause back injury. Bending with straight knees (derrick action) is dangerous compared to flexed knees and upright trunk (knee action). Horizontal components of forces are negligible. θ, the angle which the resultant force R at the hand makes with the vertical is greater for derrick action than that for knee action. See figure 2 for θ, HH, HV, FH and FV.

As foot placement distance (p) increase θ increases and with increase in grasp height (h), θ decreases. See figure 1. p and h are in cm.

Effect of the type of grasp is small and that of type of lifting action is not marked. Foot placement is the most important variable affecting the magnitude of the lifting force. The next important variable is grasp height. Vertical component of the force applied to the bar is:

$$HV = \frac{w\alpha}{p + h \tan \theta - \beta} \text{ Kg. wt.}$$

where w is the weight of subject in Kg, α is the leverage distance of the line of action of w from the effective foot pivot in cm, β the distance of this pivot from the experimental foot placement in cm.

Though p is more influential on HV than h we can assume it to be 30 cm. Average tan θ as per Whitney is 0.26 and $w\alpha$ is 1493 Kgm cm while β is 17.9 cm for derrick action. Hence,

$$HV = \frac{1493}{30 + h \tan \theta - \beta} = \frac{1493}{30 + h\ 0.26 - 17.9} = \frac{1493}{12.1 + 0.26\ h} \text{ Kg}$$

$$= \frac{1493}{12.1 + 0.26\ h} \times 2.205 \text{ lb. wt.}$$

Since p + h tan θ, in our case would always be above the lower correctly predicting limit (Whitney) we will accept the formula safe at least on lower limit basis. Since the upper limit is not specified we can take our predictions to be correct.

The maximum, steady, vertical force required for lighting at various heights of grasp is tabulated.

Grasp Height in In.	Maximum Vertical Steady Force (H.V.) output in lbs. wt.
12	164.5
14	154.5
16	145.0
18	137.0
20	130.0
22	123.5
24	118.0
26	112.5
28	108.0
30	103.2
32	99.2
34	95.5
36	91.7
38	88.5
40	87.7
42	82.5

REFERENCE

Whitney, R. J. The strength of lifting action in man. Ergonomics. Vol. 1. Number 2. Feb. 1958. pp. 101-128.

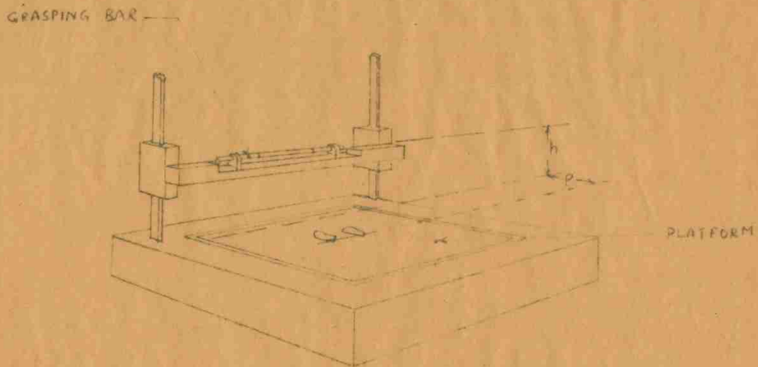


Figure 1 Sketch showing Grasp height (h) above platform surface and Foot placement distance (p) from the vertical plane including the axis of the grasping bar

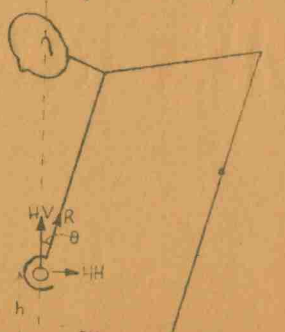


Figure 2 Sketch showing the forces at the feet (FV and FH) and at the hand (HV and HH)

1963

DETERMINING ALLOWABLE BALE SIZE AND WEIGHT FROM HUMAN ENGINEERING CONSIDERATIONS

C. W. Suggs

Although bales of tobacco for bulk curing will likely ultimately be handled mechanically, in the interim, there is still a need to consider bale size with respect to the capabilities of the men who will be working with them. Also it is likely that some manual handling of bales will be necessary due to malfunction of handling equipment.

Length. In order to permit a workman to manipulate the latch on each end simultaneously, guide the rack onto the barn rails and use the end plates as carrying handles it would be desirable to limit bale length. Median arm span according to Woodson (Human Engineering Guide) is 70.5 inches and hand length is 7.5 inches. Depending on location of the latches and how manipulated as well as location of members which might be used for handles a maximum bale length of from 54'' to 60'' should be suitable for a majority of men.

Weight. Whitney (Ergonomics 1 (2):101-128) gives an equation which predicts the maximum load which a man can bend over and lift. His equation is

$$\text{Load} = \frac{W\alpha}{p + h\tan\theta - B}$$

where
- W = body weight
- p = distance between balls of feet and centerline of weight
- h = grasp height
- θ = Angle between vertical and plane of arms (average value = 14.6°)
- α = body lever arm with respect to the weight
- B = constant = 17.5 cm.

A representative value for the product $W\alpha$ has been found to be 1471 Kg. Cm. Substituting appropriate values one has

$$\text{Load} = \frac{1471}{30 + .26\,(32) - 17.5} \cong 72\text{ Kg} \cong 160\text{ lbs.}$$

Since this is the average maximum, design weight should be decreased somewhat so that a higher percentage of the population would be able to lift the bale. It should also be pointed out that this is a maximum value describing the capacity of the individual for occasional or emergency encounters, e.g. should a bale fall off the barn rails. Routine manual handling of bales of this weight would require two men.

Suggested Nomenclature for Tobacco Bulk Curing ~~Structures~~ Systems

The bulk curing barn or structure shall consist of ~~a number of~~ one or more rooms, each room having one or more sets of rails for the suspending of the tobacco racks during the curing process. Each set of rails shall comprise a tier.

The ~~size of the barn~~ capacity rating of the structure shall be the number of racks contained in the barn times the load area of one rack, expressed in square feet.

The furnace shall consist of a fan ~~and~~ or blower with motor, a combustion unit and an air proportioning system. fuel supply, metering & control device - Temp. control eq Safety devices!

The ~~barn capacity~~ Furnace ratings shall comprise the Btu/hr. delivered to the load area and the Cfm. delivered to the load area in the absence of an actual load. standard Conditions

The air velocity through the ~~tobacco~~ system is equal to the Cfm. empty barn divided by the loading area for one tier.

CfM

Btu/hr

Max Exhaust

Recirculation

Load area

Temp control

Some Consideration Pertinent To
Bale Dimensions for Bulk Curing of Tobacco
A Human Engineering Analysis C.W. Suggs

Length

Max length such that handles at each end could be gripped is 4"-6"-8"

This assumes that handles are at top edge of package or at least that corners of package does not interfere with arms.

That is material in upper corners must be deflectable.

If package were grasped at front corners span would be about 3" longer that is

Weight

Center of gravity of package 14" thick will be 7" in front of subject.

Cantilever effects of weight must be balanced by body weight and lever arm.

Equation from Whitney (Ergonomics 1-2:114):

$$\text{Max. Load} = \frac{W\alpha}{p + h \tan\theta - B}$$

where W = body weight, Kg.

p = distance between balls of foot and centerline of weight, cm.

h = grasp height, cm.

θ = Angle between vertical and plane of arms

B = Constant

α = body lever arm (for weight)

Average value of the product $W\alpha$ is 19.8 Kg. cm.

Average value of B is 17.5 cm.

The value of θ will depend on package size but can be approximated from drawings.

$\tan\theta = 7/12 \cong .6$

The value of h will be about 95 cm.

The value of p will be about 6" = 15 cm.

Substuting:

$$\text{Max. Load} = \frac{19.8}{15 + .6\,(95) - 17.5}$$

= 28 Kg. , = 28 x 2.2 = 61.6 lbs.

Width

Packing of leaves in layers 4' deep is significant at the lower levels. Tines, even though designed for sufficient strength to support the tobacco would become too flexible for piercing the leaves. In order to keep the tine from deflecting during loading additional strength would be needed. The deflection of a cantilever beam with end loading is

$$y = \frac{Pl^3}{3EI} = \frac{Pl^3}{3E\pi}\, d^4/64$$ where d is the diameter.

In order to hold the deflection y constant as the length l increased the ratio of $\frac{l^3}{d^4}$ would be a constant; That is, $l = d^4/3$.

An alternative would be to provide a supporting device in the loading unit.

Rack Cost

Rack cost per unit of capacity should be a minimun consistent with other design characteristics.

As rack becomes wider per unit cost of side rails and fabrication would decrease. Per unit cost of tines would increase because of need for larger dia. tines. The expression for the deflection of a simple beam with uniform loading is

$$y = \frac{5Wl^3}{384EI} = \frac{5Wl^3}{384E\, bd^3/12}$$

b = beam breadth
d = beam depth

If we assume that the allowable deflection y is proportional to the span, then $y = R_1 l$. The weight on the side bars is proportional to l and width w, that is $W = R_2\, lw$

Substituting we have

$$R_1 l = \frac{5R_2 l\, l^3\, w}{384\, E\, bd^3/12}$$

Now E is a constant of the beam material. Assume that the breadth b is constant. Collect constants and call them K_o

$$K_o = \frac{l^3 w}{d^3}$$

and $d_s = K_1 l \sqrt[3]{w}$. Presumably the cost of the side bars will be proportional to d.

Tine size will depend on the width but not on the length. It can be shown to be $d_{tine} = K_2 W$.

Now assume that the cost of fabricating will be independent of the width and proportional to the length, $F_f l$, Plus a constant F related to the latch mechanism on each end. Then the cost per rack is

$$C_r = F + F_f l + M_s l \sqrt[3]{w} + M_t w.$$

Where M_s and M_t are constants or proper size to make the terms in which they appear become cost values consistent with the other terms. Cost per rack is not the final value of interest. The cost per unit of capacity C_u, is the value desired

$$C_u = C_r/LW = \frac{F}{LW} + \frac{F_f}{W} + \frac{M_s}{W^{2/3}} + \frac{M_t}{L}$$

This equation clearly has no minimum but decreases as either or both L and W increase.

Method of Handling

If racks are to be handled mechanically weight weight, length and width will not be important directly. However it should be remembered that an alternate method of handling should be available (e. g. manual) in case of mechanical failure (e. g. should one rack jump off the track).

Row width

The effect of row width on rack length could be significant. Conventional rows are 3-1/2' wide. A single skipped row will admit a

vehicle about 5' wide, that is 7 feet less 1 foot plant clearance each side. If racks are to be carried crosswise in a skip row they should not be longer than 5'.

<u>Harvester size</u>.

Concievably harvesters will be of two types

(1) Tractor mounted, (2) self-propelled, high clearance. The first type would be mounted on a light (one or two row) tractor. In this case bale weight should not surpass the capacity of the tractor. Implement weights for this size tractor are about 700 lbs. If the baling platform and the operator weight 400 lb. then a bale weight of 100 pounds would be acceptable, assuming that weight of the empty racks would be about 200 lb. The high clearance machine would be somewhat larger and would probably accomodate a heavier rack.

<u>Forcing tines through leaves</u>.

Resistance of tobacco leaves to tines will consist of two parts; (1) point resistance (puncture) (2) friction of leaves along tine. The first of these two components is independent of the thickness of the bulk. The second at any tine would be proportional to the thickness pierced. That is resistance R would be related to By thickness t by $R = C_1 + C_2t$ where C_1 and C_2 are constants. At some thickness R would become large enough to cause the tine to fail in compression.

Curing Characteristics

Bale height could have an effect on curing. Bale width (thickness) would be of importance only to the extent that nonuniform packing might take place.

Adaptability of conventional barns.

Conventional barns have at least one dimension divisible by 4 feet. The implication as to bale length is obvious.

References

McCormick, Human Engineering

Lifting - seated - atm at 90°

5th percentile is 17 & 20 lb. L & R

Mean is 52 & 56 lb. L & R

at 120° 5th percentile is 17 & 24 L & R

Mean 54 & 60 L & R

Force exerted varies with height above shoulder.

Max. force for push varied from 190 to 130 to 110 to 150 at height above the shoulder of -30, -18, 0 and +18 inches.

Woodson, Human Eng. Guide - pg. 4 - 28

Biceps strength is about 60 lb. each in lifting.

Whitney, Ergonomics, 1958 1, 2:102-128

Found max. lifting values of 41 to 64 Kg. for 8 subjects.

Values for lifting objects from 12.5 to 50 cm above the floor.

<u>Length</u>

Woodson - pg. 4 - 17

	Low	Median	High
Arm span is	60.6	70.5	79.5
Arm length		30.9	
Forward reach	29.5	34.8	39.0
Fore arm length		10.6	
Span Akimbo	31.1	36.5	4.7
Hand length	6.3	7.5	8.7

Reach for C. W. Suggs in horizontal plane 12" below shoulders is 5' 10".