0530-LP-529-0000

Warehouse Modernization and Layout Planning Guide

- Applicable to functional concept planning for new facilities or modernization of existing facilities.
- Describes basic storage and material handling state-of-the-art system concepts.
- Provides modular layouts, system selection-design criteria and comparative costs for self-help analysis of storage activities.
- Provides techniques for facility, inventory, product and transaction data analysis to be used in developing preliminary alternative functional designs.
- Furnishes guidance for developing budgetary costs and final studies for which external assistance may be required.

Department of the Navy
Naval Supply Systems Command
NAVSUP Publication 529
March 1985

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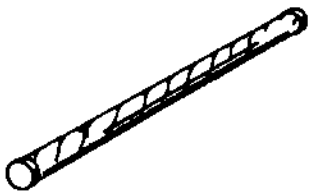
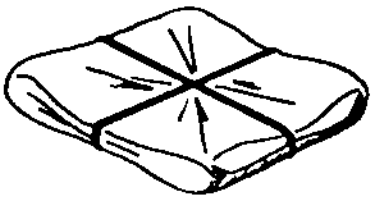
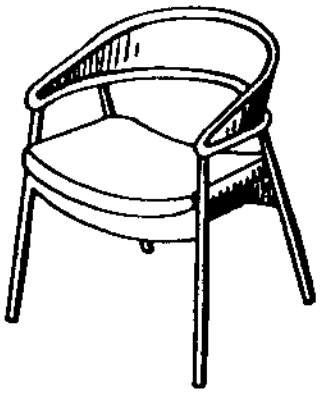
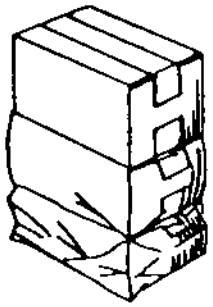
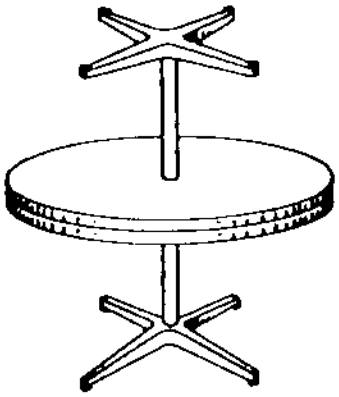


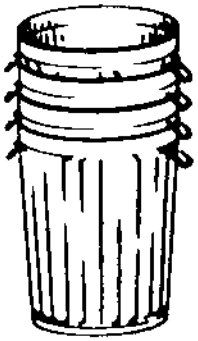




NON STACKABLE - SHAPE

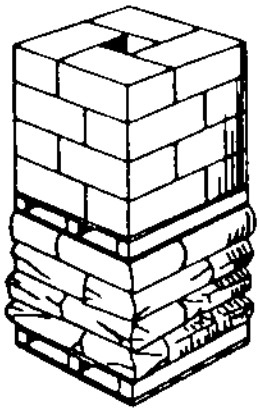


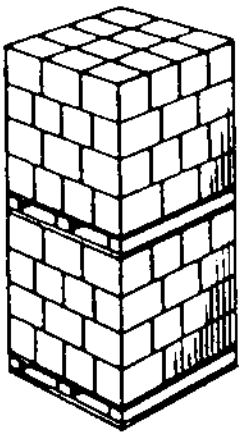




NON STACKABLE
STRENGTH OR DAMAGE

NESTABLE





STACKABLE - LIMITED HEIGHT

STACKABLE

TYPICAL EXAMPLES OF STACKABILITY

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Figure 2-9

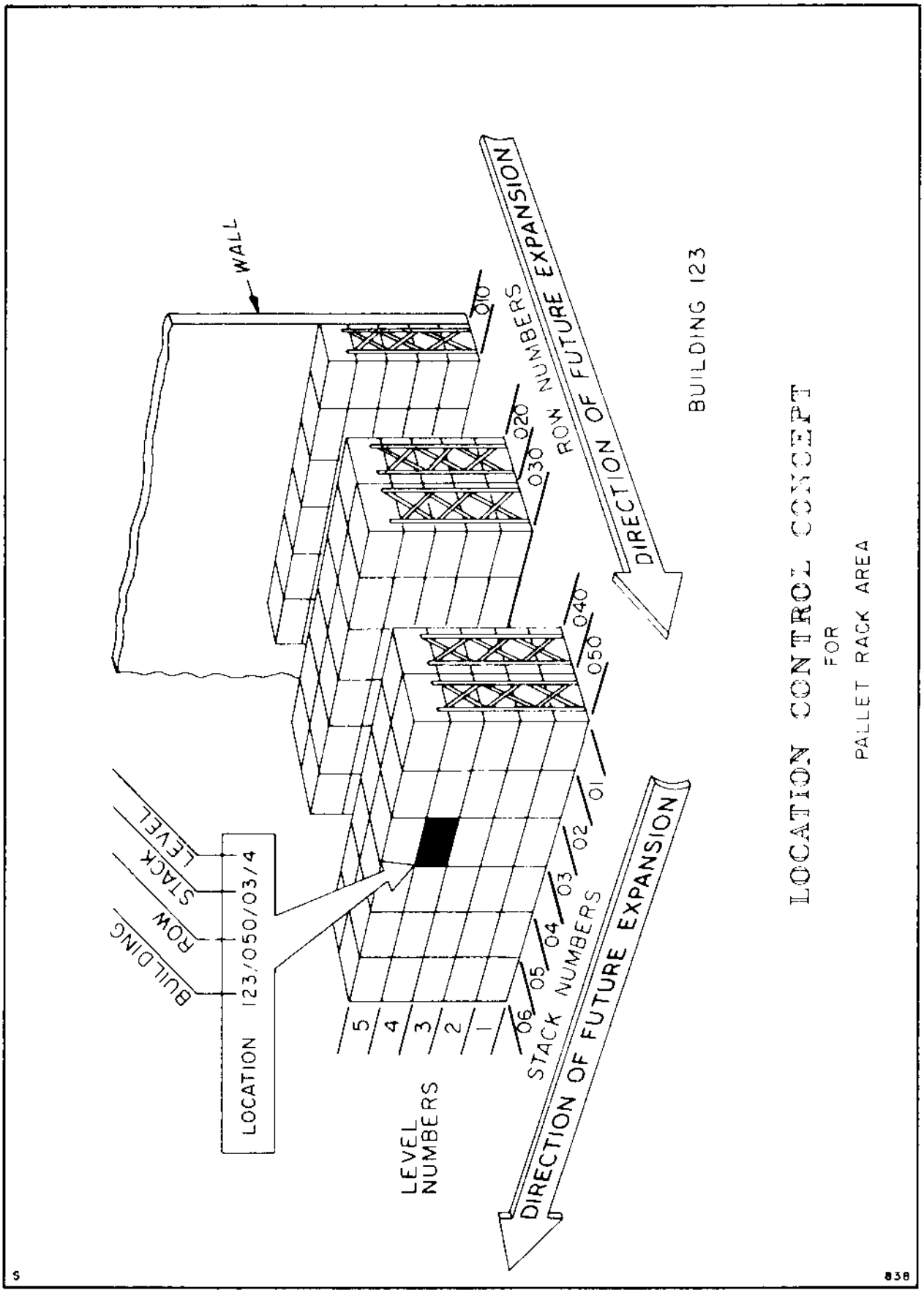

LOCATION CONTROL CONCEPT
FOR
PALLET RACK AREA
BUILDING 123
WALL
ROW NUMBERS
010
020
030
040
050
DIRECTION OF FUTURE EXPANSION
01
02
03
04
05
06
STACK NUMBERS
DIRECTION OF FUTURE EXPANSION
LEVEL NUMBERS
1
2
3
4
5
LOCATION 123/050/03/4
BUILDING
ROW
STACK
LEVEL
S
838

Figure 2-10

6.3.1 Selective Rack

The conventional beam type pallet rack consists of structural uprights joined by the pallet beams which actually support the pallet and load. Because the standard Navy pallet rack is the same depth as the pallet (40"), loads might have a tendency to fall through the beam opening. Therefore, pallet support members (load bars) which span between the beams are required to provide support for the load. See GSA/FSS Specification AA-R-0045 "Racks, Storage, Loaded Pallet".

6.3.2 Drive-in/Drive-through Rack

The drive-in rack structure consists of vertical posts with cantilever supported pallet rails. This type of structure can be made either one pallet or several pallets deep. The single pallet arrangement can be used in place of the conventional beam rack and is widely used in high rise S/R systems, where the additional support of the one load per slot design is important. When designed several pallets deep, the system becomes a high density storage system, similar to the automated deep bulk system described in Section 3, but using conventional fork lift trucks instead of automated equipment. This arrangement is shown in Figure 6-25.

The fork lift truck operating in a drive-in rack must be confined carefully so that it does not bump the racks and damage merchandise or equipment. In some cases, guide rails are used to prevent this problem. In addition, because of the rigidity of the layout pattern generated by drive-in racks, they have a tendency to develop excessive honeycombing and encourage locked stock. They also reduce the flexibility of the warehouse storage operation. In general, a drive-in rack performs the same function as floor storage for items which cannot be self-supporting in stacks. The alternative to these racks is the use of self-supporting pallet fixtures as discussed earlier. The use of drive-in racks should be minimized, and the problem of non-stackable loads should be dealt with using special pallet support devices.

6.3.3 Storage Equipment Considerations

If a shuttle table system is used, clearance is required between the bottom of the pallet and the top of the beam. To provide this space, entry bars or pallet risers are available to raise the pallet above the beams. Compared to the drive-in rack structure, the pallet riser method requires more vertical space, with the possibility of a reduction in the maximum number of vertical loads. When straddle or double reach equipment is used, a lower beam is used to raise the first load off the floor. This also reduces the total available storage height.

6.3.4 Safety Considerations

The design and selection of a particular pallet rack requires a great deal of engineering analysis and judgment. A pallet rack is a structure and must conform to structural engineering design practices and principles. It is essential that pallet racks conform to the structural design procedures of the American Iron and Steel Institute and the American Institute of Steel Construc-

(turn to page 6 - 30)

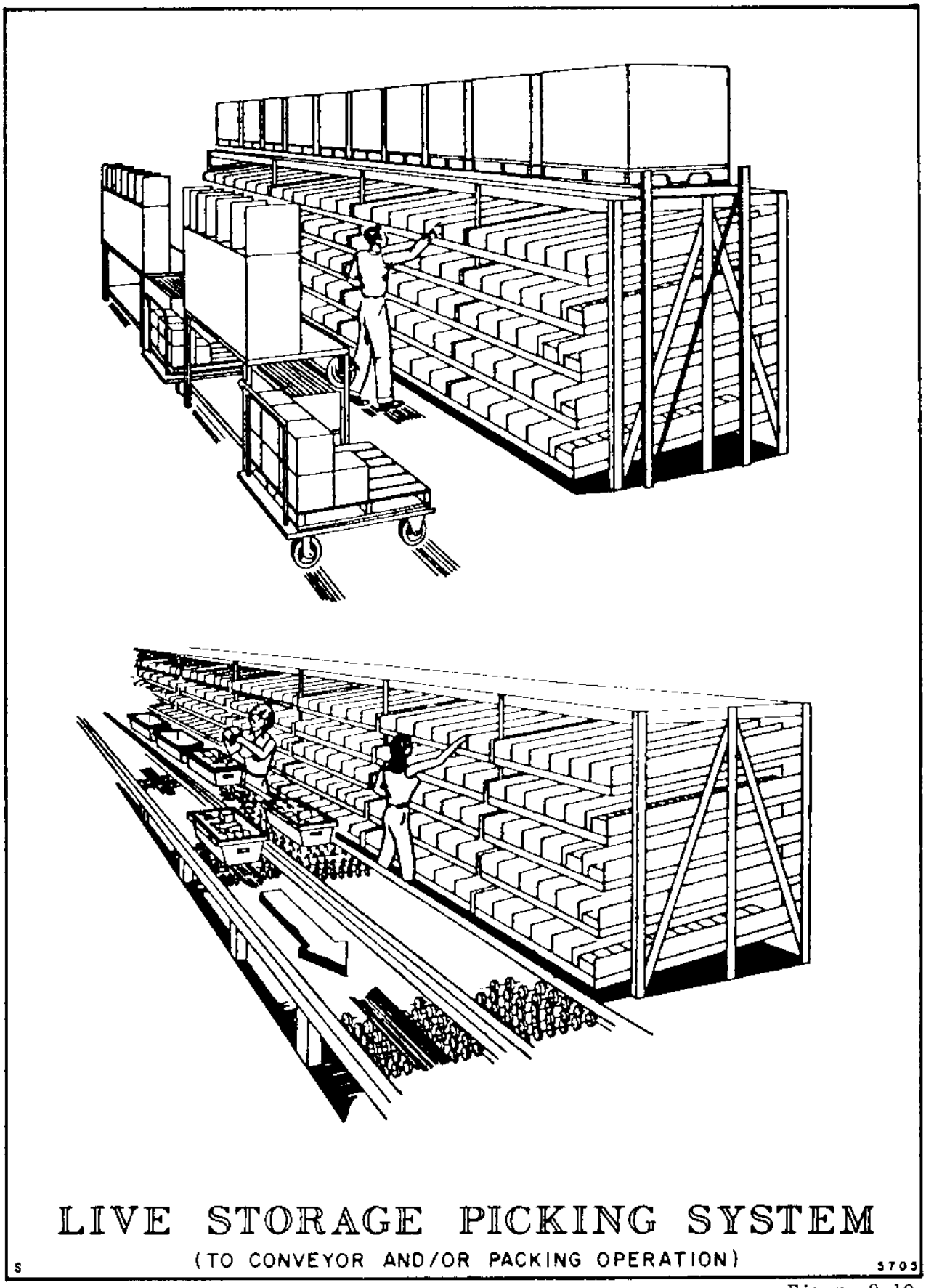
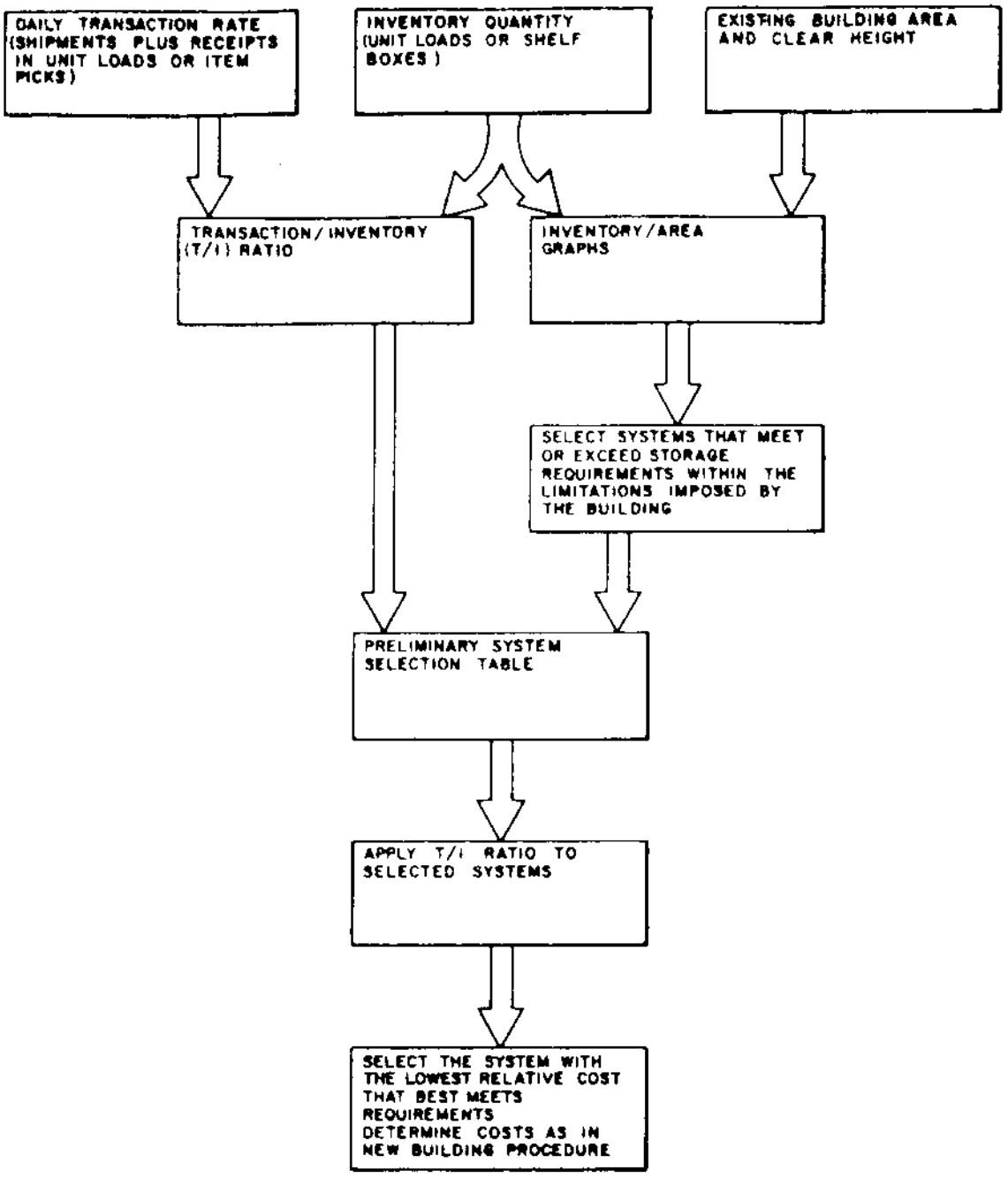

LIVE STORAGE PICKING SYSTEM
(TO CONVEYOR AND/OR PACKING OPERATION)
S
5705

Figure 8-10



SYSTEM SELECTION PROCEDURE
-EXISTING BUILDING-

Figure 15-2

AUTOMATED STORAGE/RETRIEVAL SYSTEM PALLET RACK COST ANALYSIS
Costs as of 1 October 1983

Element	Pallet Storage Levels										
	10	11	12	13	14	15	16	17	18	19	20
Upright Height	497"	541"	591"	635"	685"	729"	779"	823"	873"	917"	967"
Uprights/Pallet	0.101	0.092	0.084	0.078	0.072	0.068	0.063	0.060	0.056	0.053	0.051
Upright Cost/Inch	$1.666	$1.684	$1.701	$1.719	$1.736	$1.754	$1.772	$1.789	$1.807	$1.824	$1.842
Support Pairs/Bay	10	11	12	13	14	15	16	17	18	19	20
Support Pairs/Pallet	1	1	1	1	1	1	1	1	1	1	1
Guidance Cost/Pallet	$59.38	$53.98	$49.48	$45.67	$42.41	$39.58	$37.11	$34.93	$32.99	$31.25	$29.69
Sprinkler Levels	2	2	3	3	3	4	4	4	5	5	6
Sprinkler Heads/Pallet	0.050	0.045	0.063	0.058	0.054	0.067	0.063	0.059	0.070	0.066	0.075
Sprinkler Cost/Pallet	$6.25	$5.63	$7.88	$7.25	$6.75	$8.38	$7.88	$7.38	$8.75	$8.25	$9.38
Cost Per Pallet											
Uprights	$ 83.63	$ 83.82	$ 84.44	$ 85.14	$ 85.62	$ 86.95	$ 86.96	$ 88.34	$ 88.34	$ 88.65	$ 90.84
Beams	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00
Sprinklers	6.25	5.63	7.88	7.25	6.75	8.38	7.88	7.38	8.75	8.25	9.38
Total W/O Guidance	$117.88	$117.45	$120.32	$120.39	$120.37	$123.33	$122.84	$123.72	$125.09	$124.90	$128.22
Guidance	$ 59.38	$ 53.98	$ 49.48	$ 45.67	$ 42.41	$ 39.58	$ 37.11	$ 34.93	$ 32.99	$ 31.25	$ 29.69
Total With Guidance	$177.26	$171.43	$169.80	$166.06	$162.78	$162.91	$159.95	$158.65	$158.08	$156.15	$157.91
Conveyor/Controls per Aisle	$98,000	$98,000	$98,000	$98,000	$98,000	$98,000	$98,000	$98,000	$98,000	$98,000	$98,000
Tower & Controller per Aisle	$160,000	$163,000	$166,000	$169,000	$172,000	$175,000	$177,000	$179,000	$181,000	$183,000	$185,000
Equipment Cost/Pallet	$172.00	$158.18	$146.67	$136.92	$128.57	$121.33	$114.58	$108.63	$103.33	$ 98.60	$ 94.33

NOTES:

1. 10% linear cost increase for uprights from 10-20 storage levels
2. Beam/support cost constant at $28.00 per pallet position
3. Ratio of uprights to pallets constant at 1.013:1
4. In-rack sprinklers located at alternate pallet positions with a density of 0.25 heads per pallet stack per row of sprinklers, $125 per head.
5. Guidance consists of upper and lower guide rails and aisle electrification. Cost estimated at $250 per aisle foot. Stack cost consists of 2 pallet stacks per aisle position with 4.750 aisle feet per pair of stacks or 2.375 feet per stack at a cost of $593.75 per stack.
6. Aisle module consists of 150 floor positions per aisle.
7. Equipment depreciated on straight-line basis over 10 year life.
8. Seismic allowances for modification of pallet system costs:
   Zones 0,1 - Use baseline data; Zone 2, +20%; Zone 3, +30%; Zone 4, +38%

Table 18-11

SAMPLE CALCULATION OF A COST EQUATION
Counterbalance Truck
2 high pallet storage

Inventory Related Costs

Building Cost

1.	Building Construction Cost	$ 35.45/sq.ft.
2.	Annualized Building Construction Cost	$ 1.418/sq.ft.
3.	Annual Building Operation Cost	$ 0.50/sq.ft.
4.	Building Area per Pallet Position	30.11 sq.ft.

Annual Building Cost per Pallet Position $ 57.75

Annualized Storage Equipment Cost per Pallet Position $ 2.97

Transaction Related Costs

Labor Cost

1.	Hourly Labor Rate	$ 11.50/hr.
2.	Standard Transaction Time per Issue	5.568 min.
3.	Activity Rate	1 issue/day
4.	Working Days per Year	250 days
5.	Annual Labor Hours per Daily Transaction	23.20 man-hours

Annual Labor Cost per Daily Transaction $ 266.80

Vehicle Cost

1.	Hourly Vehicle Operation Cost	$ 1.90/hr.
2.	Annual Labor Hours per Daily Transaction	23.20 man-hours

Annual Vehicle Operation Cost per Daily Transaction $ 44.08

Cost Equations

With Building Cost

(Building Cost + Storage Equipment Cost) x Inventory +
(Labor Cost + Vehicle Cost) x Transactions = Annual System Cost

($57.75 + $ 2.97)Inventory + ($266.80 + $44.08)Transactions =
Annual System Cost = $60.72 I + $310.88 T

Without Building Cost

(Building Operation Cost + Storage Equipment Cost) x Inventory +
(Labor Cost + Vehicle Cost) x Transactions = Annual System Cost

($15.06+$ 2.97)Inventory + ($266.80+$44.08)Transactions =
Annual System Cost = $18.03 I + $310.88 T

Table 18-12

COST EQUATIONS

BINNABLES ORDER PICKING SYSTEMS

System	Storage Levels	New Construction	Existing Building
Manual Pick Cart	7	$ 0.98 I + $ 90.75 T	$ 0.61 I + $ 90.75 T
	14	$ 0.80 I + $ 90.75 T	$ 0.62 I + $ 90.75 T
	21	$ 0.77 I + $ 90.75 T	$ 0.62 I + $ 90.75 T
Order Picking Truck	13	$ 0.82 I + $ 71.71 T	$ 0.58 I + $ 71.71 T
	20	$ 0.71 I + $119.37 T	$ 0.53 I + $119.37 T
	27	$ 0.66 I + $121.88 T	$ 0.52 I + $121.88 T
	34	$ 0.64 I + $124.51 T	$ 0.51 I + $124.51 T
Manned S/R Machine	20	$ 0.98 I + $152.19 T	$ 0.83 I + $152.19 T
	27	$ 0.85 I + $151.81 T	$ 0.73 I + $151.81 T
	34	$ 0.77 I + $151.62 T	$ 0.68 I + $151.62 T
Carousel	7	$ 2.44 I + $ 85.42 T	$ 2.06 I + $ 85.42 T
	14	$ 2.78 I + $100.27 T	$ 2.57 I + $100.27 T
	21	$ 3.00 I + $116.62 T	$ 2.84 I + $116.62 T
Mini-S/R Machine	20	$ 1.30 I + $151.06 T	$ 1.21 I + $151.06 T
	31	$ 1.01 I + $154.87 T	$ 0.94 I + $154.87 T
	42	$ 0.86 I + $141.05 T	$ 0.80 I + $141.05 T

I = Inventory in shelf boxes T = Transactions in 1348-1 orders per day

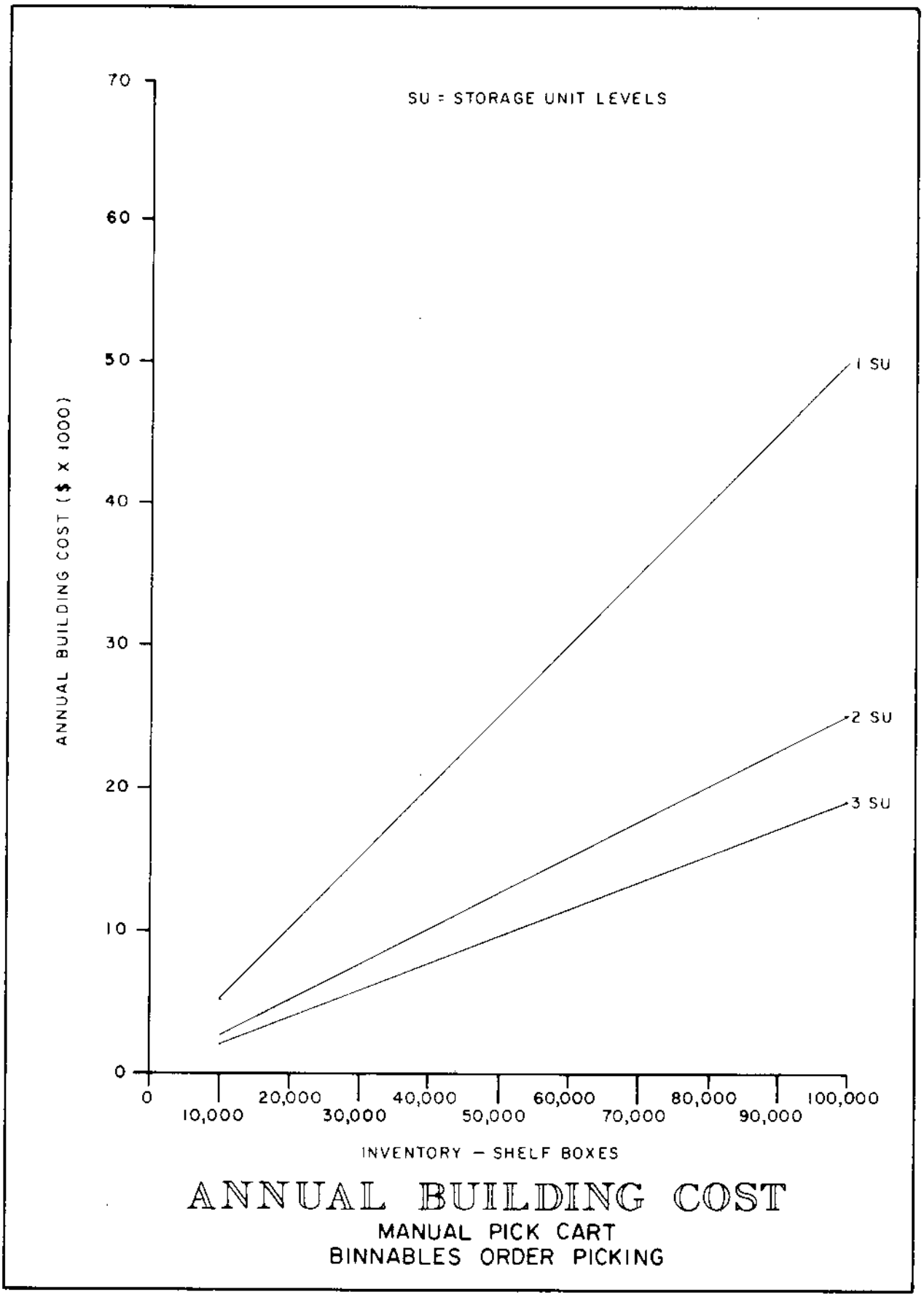
Cost base of 1 October 1983

Table 18-20

AVERAGE RACKABLES ORDER PICKING TRANSACTION TIME
(Minutes per Line Item Issue Including 20% Personal Fatigue and Delay Allowance)
(Based on Average Inventory of 2,000 Pallet Positions per Order Picking Module)

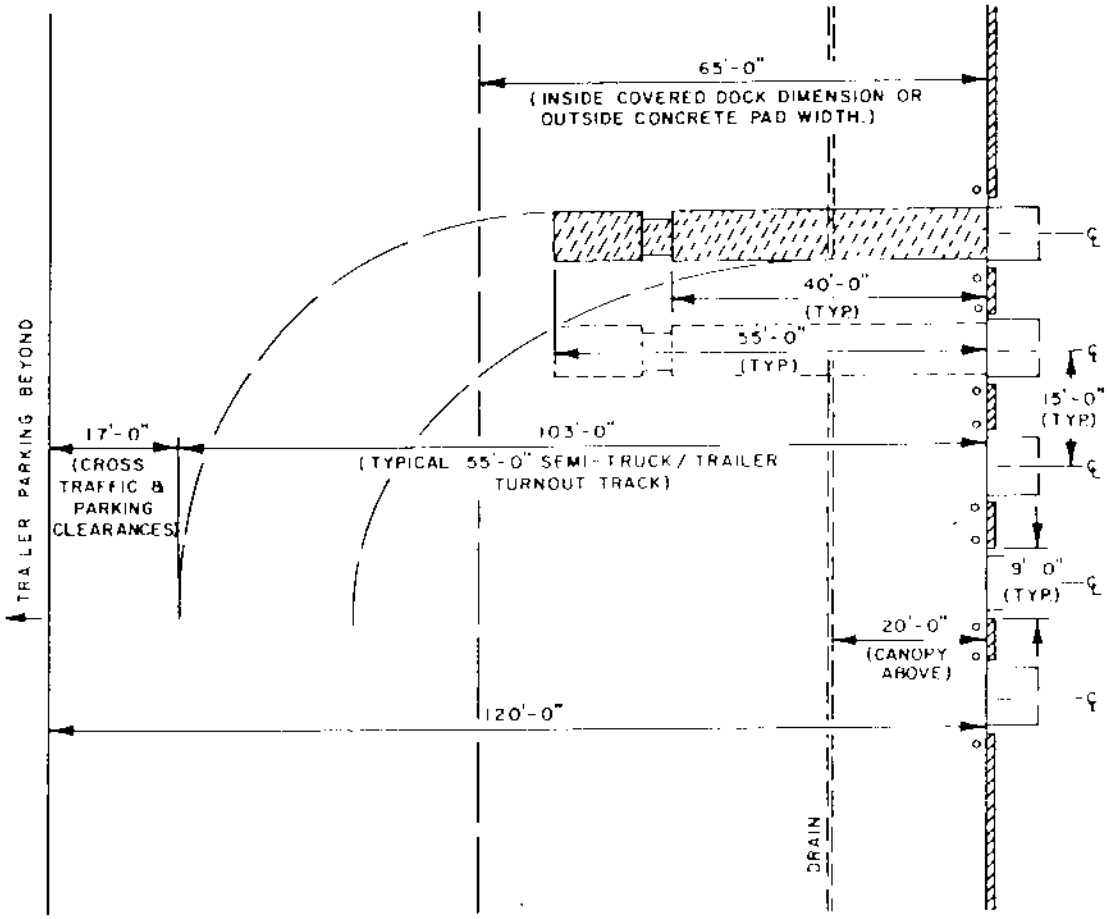
System	Storage Levels	Density Factor	Average Height	Travel Time	Maneuver Time	Pick/ Document Time	Lift/ Lower Time	Replenish/ Document Time	Misc. Time	Total Time
Order Picking Truck	2	0.86	4.00	1.977	0.544	1.356	0.057	0.048	0.028	4.010
	3	1.30	6.00	1.388	0.386	1.356	0.083	0.048	0.028	3.289
	4	1.73	8.00	1.101	0.309	1.356	0.108	0.048	0.028	2.951
	5	2.16	10.00	0.929	0.263	1.356	0.134	0.048	0.028	2.758
Man-Up Turret Truck	4	1.73	8.00	0.450	0.195	1.320	0.143	0.028	0.074	2.212
	5	2.16	10.00	0.381	0.162	1.320	0.192	0.028	0.074	2.157
	6	2.59	12.00	0.335	0.139	1.320	0.240	0.028	0.074	2.136
	7	3.03	14.00	0.301	0.122	1.320	0.288	0.028	0.074	2.134
	8	3.46	16.00	0.277	0.110	1.320	0.336	0.028	0.074	2.145
	9	3.89	18.00	0.258	0.100	1.320	0.384	0.028	0.074	2.165
	10	4.32	20.00	0.242	0.093	1.320	0.432	0.028	0.074	2.190
Hybrid Truck	7	3.00	14.50	0.255	0.074	1.320	0	0.028	0.074	1.752
	8	3.43	16.50	0.245	0.068	1.320	0	0.028	0.074	1.736
	9	3.86	18.50	0.238	0.063	1.320	0	0.028	0.074	1.724
	10	4.29	20.50	0.233	0.060	1.320	0	0.028	0.074	1.715
	11	4.71	22.50	0.230	0.057	1.320	0	0.028	0.074	1.709
	12	5.14	24.50	0.228	0.054	1.320	0	0.028	0.074	1.705
	13	5.57	26.50	0.227	0.052	1.320	0	0.028	0.074	1.702
	14	6.00	28.50	0.227	0.050	1.320	0	0.028	0.074	1.700
	15	6.43	30.50	0.227	0.048	1.320	0	0.028	0.074	1.698
	16	6.86	32.50	0.228	0.047	1.320	0	0.028	0.074	1.698
Manned S/R Machine	10	4.32	20.50	0.441	0.026	1.320	0.016	0.028	0.074	1.905
	11	4.76	22.50	0.407	0.026	1.320	0.016	0.028	0.074	1.872
	12	5.19	24.50	0.381	0.026	1.320	0.016	0.028	0.074	1.846
	13	5.62	26.50	0.359	0.026	1.320	0.016	0.028	0.074	1.824
	14	6.05	28.50	0.341	0.026	1.320	0.016	0.028	0.074	1.806
	15	6.49	30.50	0.326	0.026	1.320	0.016	0.028	0.074	1.790
	16	6.92	32.50	0.313	0.026	1.320	0.016	0.028	0.074	1.778
	17	7.35	34.50	0.302	0.026	1.320	0.016	0.028	0.074	1.767
	18	7.78	36.50	0.293	0.026	1.320	0.016	0.028	0.074	1.758
	19	8.22	38.50	0.285	0.026	1.320	0.016	0.028	0.074	1.750
	20	8.65	40.50	0.279	0.026	1.320	0.016	0.028	0.074	1.743

Table 18-21



ANNUAL BUILDING COST

MANUAL PICK CART
BINNABLES ORDER PICKING



TYPICAL TRUCK APRON LAYOUT

Figure 23-14

TYPICAL TRUCK AND RAIL VEHICLE AND DOCK HEIGHTS

Type of Truck	Bed Height (inches)		Overall Height		Dock Height (inches)	Minimum Dock Leveler Length(Ft.)
	Minimum	Maximum	Minimum	Maximum		
Container	56	62	12'-2"	13'-6"	52	6 to 10
Reefer	50	60	12'-6"	13'-6"	52	6 to 8
Flatbed	48	60	---	---	48(a)	6 to 12
Double Axle Semi	46	56	12'-0"	13'-6"	48(b)	6 to 8
Straight Semi	44	52	12'-0"	13'-6"	48(b)	8
City Delivery	42	48	11'-0"	12'-6"	48	6 to 8
Stake Body	42	48	---	---	48	6 to 8
High Cube Van	32	38	13'-0"	13'-6"	43	8 to 12
Furniture Van	24	36	13'-0"	13'-6"	30(c)	8
Step Van	20	30	8'-6"	10'-0"	30(c)	6 to 10
Panel Truck	20	24	8'-0"	9'-0"	30(c)	8 to 10
Low Boy	20	24	---	---	30(c)	8 to 10
Box Car	41	44	---	---	44	6(d)
Reefer Rail Car	46	52	---	---	48	5 to 6(d)

(a) Range of 48"-52".

(b) 50" if serving semis only.

(c) Nominal 48"-50" dock recommended with exterior ramp to elevate truck to provide nominal 30" dock height.

(d) Minimum length available determined by required clearance between rail car and dock.

Table 23-9

23.5.7 Door Size

Typical overhead doors for truck docks are 8 to 10 feet high and 9 feet wide. An 8 foot high door will typically provide a 12 foot high opening from the ground to top of door. This leaves approximately 15 to 18 inches of unusable trailer height due to door clearance when loading a standard 13'-6" trailer. A 9 foot high door allows sufficient space to load highly compacted loads without encountering overhead restrictions due to door height. A 10 foot high door will permit full access to the highest truck. Figures 23-17 and 23-18 show typical dimensions for a flush dock door.

23.5.8 Interior Layout

Interior layout of docks includes loading and unloading areas as well as staging and accumulation areas. Figure 23-19 shows typical inside dimensions for a dock. These dimensions allow for towline and load staging areas.

Load accumulation space must be estimated using typical shipment and truck loading data. The amount of material to be accumulated will increase as the order picking rate exceeds the loading rate. The space will reach a peak and then decrease as order picking ends and shipping removes the backlog. Space estimates can be developed by maintaining a work sheet similar to that in Figure 23-20. The working day is divided into time blocks and the amount of material picked and shipped is recorded. The data is converted to area using density and area conversion factors derived from the characteristics of material processed by a particular facility.

23.5.9 Dock Levelers and Accessories

Dock design is completed by the addition of accessories which enhance the performance, safety, and security of dock operations. Dock levelers permit fork trucks to rapidly load and unload trailers by providing a permanently mounted bridge to the trailer which adjusts to elevation differences between the trailer and dock.

Two factors are critical in dock leveler selection. The first factor is length, which determines the maximum grade which must be negotiated by a fork truck. A maximum grade of 10% should not be exceeded. Recommended dock leveler lengths for various dock heights were listed previously in Table 23-9.

The second factor in dock leveler selection is capacity. Dock levelers are subjected to substantial impact loads caused by the motion of the fork truck, truck and load weight, and approach grade. Table 23-10 provides a summary of estimated life based on capacity, use, and gross load. The life of a given capacity dock leveler, as shown in the table, can range from less than 5 years to more than 20 years, depending on use, gross load, and rated capacity.

Dock weather seals (Figure 23-21) are a useful energy saving accessory which seals the gap between the truck and door and reduces the infiltration of outside air into the warehouse. Weather seals are available as either foam pad door seals or flexible member dock shelters. Each type has particular advantages and disadvantages.

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STANDARD OPERATION SEQUENCE

Counterbalanced Fork Truck - Pallet Storage

Operation Scenario

Unload loads from pallet rack
Move to staging area
Stack loads in staging area
Return to pallet rack

Operation Sequence

Element	Description	Rate (Minutes)	Activity Frequency Per Cycle	Total Time Per Cycle
1	Document Processing	0.110	1	0.110
2	Count pieces/process docs	0.880	1	0.880
3	Mount/Dismount	0.450	1	0.450
4	Raise forks	R1xL1	1	R1(L1)
5	Run in	0.120	1	0.120
6	Lift load	0.050	1	0.050
7	Run out	0.082	1	0.082
8	Turn & stop	0.090	1	0.090
9	Lower forks	R2xL1	1	R2(L1)
10	Accelerate	0.030	1	0.030
11	Travel to staging	R3xD1	1	R3(D1)
12	Stop	0.028	1	0.028
13	Raise forks	R1xL2	1	R1(L2)
14	Run in	0.120	1	0.120
15	Place load	0.050	1	0.050
16	Run out	0.082	1	0.082
17	Lower forks	R2xL2	1	R2(L2)
18	Accelerate	0.030	1	0.030
19	Travel to storage	R3xD2	1	R3(D2)
20	Turn and stop	0.090	1	0.090
21	Intermediate starts/stops	0.055	n	0.055(n)

Summary Equation

Time = 2.212 + n(0.055) + R1(L1+L2) + R2(L1+L2) + R3(D1+D2) min.

Pallets handled per cycle = 1.0