CO652.0710 State Supplement

(a) General Information

This part contains technical information required for the design of various irrigation practices. The practices covered herein are primarily engineering practices and are required for the efficient development and operation of irrigation systems.

(b) Tailwater Recovery System - Code 447

(1) Procedure for Design of Irrigation Tailwater Embankment Ponds

Embankment fills made to impound irrigation tailwater will meet the design requirements and specifications listed in the Colorado Standard and Specifications for Pond - Code 378.

In addition to the reasons cited in 652.0705 “Irrigation runoff, tailwater recovery and reuse,” tailwater recovery systems may be considered for one or more of the following reasons:

- Section 208 of the Pollution Control act generally treats tailwater as a non-point source of pollution.
- Tailwater and reuse systems are used in areas of deep-well irrigation because they require much less power to pump water from a tailwater pit than from the aquifer.

Storage requirements for irrigation tailwater will be determined using the same criteria as for tailwater pits.

(2) Procedure for Design of Irrigation Tailwater Pits

(i) Depth-Design water surface shall be at the flowline elevation of the inlet structure or 1 foot (0.3 m) below the lowest irrigable land elevation adjacent to the pit, whichever is lower. Retrievable tailwater depth shall be a minimum of 5 feet (1.5 m) and a maximum of 12 feet (3.6 m). Excavated depth (below design water surface elevation) shall be design water depth plus 1 foot (0.3 m).

(ii) Slopes and Top Width-Excavated and embankment slopes shall not be steeper than 3:1, except 2:1 slopes may be used for the sides of the pit in soils that will be stable at the slope. Slopes will usually not be flatter than 4:1, except that one or both ends may be flattened to 6:1 for ease of construction and cleanout.

Minimum top width of berms and dikes shall be 8 feet (2.4 m).

(iii) Mechanical Inlet Structures-Inlet structures shall be provided to convey the tailwater and/or storm runoff into the pit without erosion damage to the entrance channel or sides of the pit. These structures may consist of chutes, drop structures, or pipes (minimum size - 10 inches [25 cm] in diameter) using corrugated metal, welded steel, plastic, concrete, or other approved material. Structures will be designed in accordance with the Colorado Standards and Specifications. The inlet structures must have the capacity to satisfy the operating needs of the system.

(iv) Emergency Spillway or Storm Bypass-Pits shall be surrounded by berms and dikes to prevent surface water from entering the pits at points other than the mechanical inlet structure. A storm bypass or emergency spillway shall be provided which will pass the runoff from a 25-year, 24-hour frequency A.M.C. II storm. Tops of the berms and dikes shall be at least 1 foot (0.3 m) above the maximum water surface in the pit or the spillway, whichever is higher, when passing this storm.

(v) Size

Condition A--Pumpback is intermittent. Volume of storage shall be designed on the basis of the following:

Select Ti, which is the irrigation set time in hours. Ti is listed in Column 11, part 4, of the Colorado Irrigation Guide. The Ti selected should represent the most restrictive design condition for the system. For example, if both border and furrow irrigation methods are planned, furrow irrigation with a high water demand crop (such as corn) should be used to select Ti.

The number of sets (N) to be irrigated with pumpback water per pumpback cycle is usually 2. The maximum number is 2 and the minimum is 1.

Determine whether or not tailwater from the pumpback pump also enters the pit.

Tp is the pumpback time in hours, Tp = N x Ti.

Discharge rate (q) in gallons per minute of the pumpback pump is determined by multiplying the primary source (Q) in gallons per minute by a variable factor (Ca). Values of Ca vary according to soil intake families. Table CO7-1 below lists the values of Ca for the various intake families.

Table CO7-1

Intake Family	Ca Factors		
	Maximum	Median	Minimum
0.1 to 0.3	0.80	0.60	0.40
0.5	0.60	0.46	0.33
1.0 to 3.0	0.40	0.30	0.20

Values of q may be adjusted $\pm$10 percent if needed to fit the pump discharge rates of commercial suppliers.

The rate of tailwater flow into the collection pits is based on the intake rates of the contributing areas along with the discharge rates of wells, turn outs, and pumps delivering the irrigation water. Use a decimal percentage (%) of Q returning as tailwater from the percentages shown in Table CO7-2 for the soil intake families listed.

Table CO7-2

Intake Family	Percentage (% or %*) of Primary (Q) or Pumpback (q) Flow Delivered as Tailwater
0.1 to 0.3	20
0.5	15
1.0 to 3.0	10

Also select from Table CO7-2 a decimal percentage (%*) of pumpback flow q returning as tailwater.

Find the total of the average field tailwater from the primary source (%Q) and the average tailwater from the pumpback flow (%*q) or (%Q + %q). This is the total tailwater inflow into the pit.

To keep the tailwater system in equilibrium, the pumpback rate q of the pumpback pump minus the total inflow (%Q + %q) must equal the volume of the tailwater pit (Vs) in acre-inches,

or storage = (outflow - inflow)

or $Vs = \frac{q - (\%Q + \%q)}{450} \times Tp$ = acre-inches

Example:

Given: Richfield silt loam, intake family = 0.3
Q = 1,000 gpm Slope Group = 0.2%
Ti = 16.3 hrs. N = 2

Find: Tp, q, %Q, %*q, and Vs

Tp = N x Ti = 2 x 16.3 = 32.6 hrs.

From Table KS7-1, Ca = 0.6 (median value)
q = Ca x Q = 0.6 x 1,000 = 600 gpm

From Table CO7-2, % = 20%, %* = 20%,
then %Q = 0.20 x 1,000 = 200 gpm,
%*q = 0.20 x 600 = 120 gpm

$$Vs = \frac{q - (\%Q + \%^*q) \times Tp}{450}$$

$$Vs = \frac{600 - (200 + 120) \times 32.6}{450}$$

= 20.3 acre-inches

Condition B--Where continuous pumping is desired and the inflow is sufficient both in rate and duration to sustain such a system, the sump (as a minimum) needs to be only large enough to accommodate the pumping.

Pumpback (once started) is continuous as long as the irrigation continues uninterrupted. The maximum value of N shall be one (1). Pumpback rate (q) and the volume of storage (Vs) are determined as shown below.

The following equations may be used to determine the pumpback rate (q) in gallons per minute:

$$q = \frac{\%}{1 - \%^*} \times Q, \text{ where } \frac{\%}{1 - \%^*} = Cb$$

or

$$q = Cb \times Q$$

Q, q, %, and %* are the same units as used for Condition A.

Cb factors used to determine q are found in Table KS7-3.

Table CO7-3 Cb Factors

Estimated Decimal % of Discharge Q Flowing into the Pit											
0.10				0.15				0.20			
Estimated Decimal % of Pumpback Rate q Flowing into the Pit											
None	0.10	0.15	0.20	None	0.10	0.15	0.20	None	0.10	0.15	0.20
Pumpback Factor Cb											
0.100	0.111	0.118	0.125	0.150	0.167	0.177	0.188	0.200	0.222	0.236	0.250

Volume of tailwater storage (Vs) needed is determined using the following equation:

$$Vs = \frac{(\%Q) \times Ti}{450} = \text{acre-inches}$$

Example:

Given: Q = 1,000 gpm, Ti = 16.3 hrs., % = 0.20, %* = 0.20

Find: Cb, q, and Vs

$$Cb = \frac{\%}{1 - \%^*} = \frac{0.20}{1 - 0.20} = 0.25$$

or refer to Table KS7-3 to find Cb

q = Cb x Q = 0.25 x 1,000 = 250 gpm

$$Vs = \frac{(0.20 \times 1{,}000) \times 16.3}{450}$$

= 7.2 acre-inches

(vi) Excavated Volume--Approximate excavated volume (Ve) may be found as follows:

Ve = 175 x Vs (ac. in.) = cubic yards cu. yd.)
where 175 is the conversion from ac. in. to cu. yd. with the excavated soil density at 77%.

Condition C--To provide for adequate storage (gallons) for intermittent pumpback systems not indicated, use the following equation:

$$\text{Pond Volume (V)} = \frac{Q \times T}{3} \quad \text{or} \quad Vs = \frac{q \times Tp}{3}$$

Where:
Q = volume of pumpback system (gpm)
T = irrigation set time (hours)

(vii) Figuring Length, Width, and Volume for Excavated Pits

Volume Equation is: $V = \frac{d}{162} \times (A_1 + 4M + A_2)$

Where:

d = depth (feet)

A_1 = top area (ft^2)

M = medium area (ft^2)

A_2 = bottom area (ft^2)

162 = 27 ft^3/yd^3 x 6 (sum of areas)

Computing length of pit bottom for desired volume, depth, and width:

Where:

l = bottom length of the pit (feet)

V = Volume (cubic yards)

w = bottom width (feet)

d = depth (feet)

Table CO7-4 Equation for Length at Bottom of Pit

Side Slope	End Slope	Equation for Bottom Length of Pit (1)
3:1	3:1	$\frac{27V - 12d^3 - 3d^2w}{3d^2 + dw}$
2:1	4:1	$\frac{81V - 32d^3 - 12d^2w}{6d^2 + 3dw}$
3:1	4:1	$\frac{27V - 16d^3 - 4d^2w}{3d^2 + dw}$
4:1	4:1	$\frac{81V - 64d^3 - 12d^2w}{12d^2 + 3dw}$
3:1	6:1 - 4:1	$\frac{27V - 20d^3 - 5d^2w}{3d^2 + dw}$

Example:

Given: Storage volume (Vs) of a pit = 20.3 ac-inches
Side Slopes = 3:1, End Slopes = 6:1 - 4:1
Depth = 8', Bottom Width = 50'

Find: Estimated excavation volume (Ve), bottom length, and actual excavated volume

Ve = 175 x Vs

Ve = 175 x 20.3 = 3,552.5, use 3,553 cu. yds.

From Table CO7-4, for w = 50', d = 8', 3:1 side slope and 6:1-4:1 end slope

$$L = \frac{27V - 20d^3 - 5d^2w}{3d^2 + dw}$$

$$L = \frac{(27x3553) - (20x8^3) - (5x8^2x50)}{(3x8^2) + (8x50)}$$

$$= \frac{(95{,}931) - (10{,}240) - (16{,}000)}{(192) + (400)}$$

$$= \frac{69{,}691}{592} = 117.7, \text{ use 118 feet}$$

Actual excavated volume:

$$Ve = \frac{d}{162} \times (A_l + (4x\ M) + A_2)$$

$$= \frac{8}{162} (198 \times 98 + 4 (158 \times 74) + 50 \times 118)$$

$$= \frac{8}{162} (72{,}072) = 3{,}559 \text{ cu. yds.}$$

(c) Irrigation Water Conveyance, Pipeline - Codes 430AA Through 430HH, 431

This section summarizes design criteria for irrigation pipelines and includes various technical aids used in pipeline design. For detailed information, refer to the following standards and specifications contained in the Colorado Field Office Technical Guide, Section IV.

- Irrigation Water Conveyance, Aluminum Tubing Pipeline - Code 430AA
- Irrigation Water Conveyance, Asbestos-Cement Pipeline - Code 430BB
- Irrigation Water Conveyance, Non-reinforced Concrete Pipeline - Code 430CC (includes rubber gasket joint, mortar joint, and cast-in-place pipe)
- Irrigation Water Conveyance, High-Pressure, Underground, Plastic Pipeline - Code 431 (includes PVC, ABS, and PE plastic pipe)
- Irrigation Water Conveyance, Low-Pressure, Underground, Plastic Pipeline - Code 430EE (includes PVC, ABS, and PE plastic pipe)
- Irrigation Water Conveyance, Steel Pipeline - Code 430FF
- Irrigation Water Conveyance, Reinforced Plastic Mortar Pipeline - Code 430GG
- Irrigation Water Conveyance, Rigid Gated Pipeline - Code 430HH (includes Aluminum and PVC gated pipe)

(1) Design Criteria Summary

(i) Working Pressure-The maximum allowable working pressure is that pressure at which the pipe is warranted to operate continuously without failure. All pipelines should be designed to operate at a pressure less than or equal to the working pressure. Working pressure varies greatly from one pipe material to another; refer to the specific pipeline standard for detailed criteria.

(ii) External Load Limit--This is the maximum allowable load due to soil and vehicle weight that may be applied to the pipe. This factor is usually controlled by placing limits on the maximum and minimum amount of fill that may be placed over a pipeline.

(iii) Capacity--The pipeline shall be designed to have sufficient flow capacity to deliver the amount of water necessary to meet planned irrigation requirements. Where water is supplied by a well, the pipeline is generally designed to carry the total well output.

(iv) Velocity--Some pipe materials have a maximum velocity limitation. This limitation is usually imposed to minimize damage from surge pressures. The following standards contain velocity limitations:

- 430BB, 430EE, 430GG, 431 - 5 ft/sec maximum
- 430HH - 7 ft/sec maximum

(v) Friction Losses--This section indicates the minimum allowable roughness coefficient to be used in calculating pressure or head loss in a pipeline due to friction.

(vi) Outlets--These are appurtenances to the pipeline that deliver water to a field or another water conveyance or storage area. Typical examples include line gate valves, risers and alfalfa valves, and hydrants.

(vii) Check Valves--These are devices that prevent reverse flow back into a pump and/or well after the pump is shut down. Check valves help to prevent pump damage and help minimize the chance of polluted water in the pipeline flowing back into the well. Check valves are required on all NRCS jobs.

(viii) Stands--A stand is a device used to convey water from the source of supply into the pipeline. In most cases, the stand is installed between the pump discharge and the beginning of the pipeline. Stands are generally constructed of steel and aid in controlling air entrapment, surge pressure, and vacuum or negative pressure.

(ix) Vents--A vent is a vertical conduit attached to the pipeline that is open on one end to the atmosphere. The purpose of a vent is to allow for overflow when pressure exceeds maximum allowable working pressure. Vents are rarely used at this time, having been replaced by pressure relief valves.

(x) Pressure Relief Valves--These valves are set to overflow when a specified pressure is reached. This valve protects the pipeline from rupture due to excessive pressure.

Pipe materials conforming to 430AA, 430BB, 430FF, 431 - Pressure relief valves shall be no smaller than 1/4 the nominal pipeline diameter and shall be set to open at a pressure no greater than 5 psi above the pressure rating of the pipe.

Pipe materials conforming to 430CC and 430EE- Pressure relief valves shall have the capacity to discharge the design flow rate of the pipeline at a pressure no greater than 50% more than the working pressure of the pipe. The valves should be set to open at the pipe working pressure.

Pipe materials conforming to 430GG shall conform to both of the above-stated criteria-

Pressure relief valves are to be installed on all pump stands and at the end of the pipeline if there is no valve installed there. On a system that does not have a pump stand, a pressure relief valve shall be installed between the check valve and the beginning of the pipeline.

(xi) Air and Vacuum Release Valves-These valves allow air to escape during pipeline filling and allow air to enter the line to prevent vacuum formation during draining operations. Air and vacuum release valves are to be installed at the following points:

- On the pump stand
- At any summit in the pipeline
- At the end of the pipeline
- On both sides of any in-line control device, such as a line gate valve or hub end gate
- At any location where there are changes in pipeline grade in a downward direction of flow greater than 10 degrees (18%)

Refer to the specific standard for criteria regarding size requirements for air and vacuum release valves.

(xii) Drainage--Provisions for draining the pipeline shall be made if recommended by the manufacturer or required to prevent damage from freezing.

(xiii) Flushing--A valve shall be installed at the end of the pipeline to allow for flushing if a sediment accumulation hazard exists.

(xiv) Thrust Control--Thrust blocks or anchors are to be installed wherever there is an abrupt change in pipeline grade, alignment, or reduction in pipe size. Thrust blocks absorb the axial thrust at these locations, thereby preventing rupture or separation of the pipeline.

(xv) Materials Protection--Certain pipe materials require protective measures to prevent early failure from chemical attack. Aluminum and steel require protection from corrosion. Sulfates and salts may degrade concrete pipe. These substances may occur in irrigation water, the soil in contact with the pipeline, or both.

Refer to Figure CO7-5 for an example of a typical pump installation including appurtenances.

(2) Design Tables

The following design tables may be used in the design of pipeline systems. Included are tables for friction loss in various pipe materials and appurtenances, along with size and capacity guidelines for pressure relief valves and air and vacuum release valves installed on low-pressure plastic pipelines.

For plastic pipelines with working pressures greater than 50 psi, refer to Exhibit 3-7 in the National Engineering Handbook Series Part 650, Engineering Field Handbook, for head loss tables.

Figure CO7-5 Typical Pump Installation

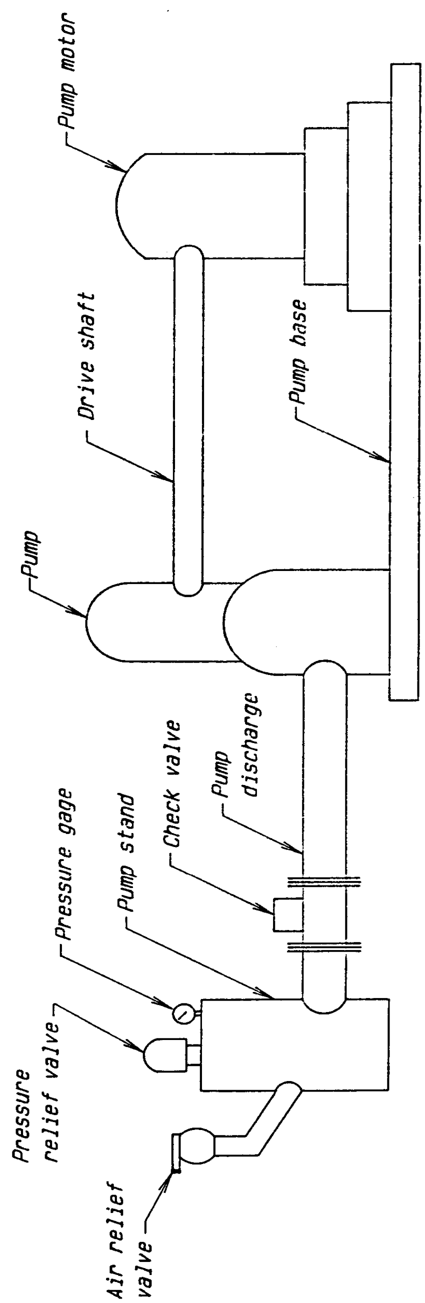


Table CO7-6 Friction Loss in 22 PSI PVC Pipe (ft./1,000 ft.)

FLOW	PIPE SIZE (INCHES)									
GPM	4	6	8	10	12	14	15	18	21	24
100	**5.77**	**0.80**	**0.20**	**0.07**	**0.03**	**0.01**	**0.01**	**0.00**	**0.00**	**0.00**
200	**20.82**	**2.89**	**0.71**	**0.24**	**0.10**	**0.05**	**0.03**	**0.01**	**0.01**	**0.00**
300	***	**6.12**	**1.51**	**0.51**	**0.21**	**0.10**	**0.07**	**0.03**	**0.01**	**0.01**
400	***	**10.43**	**2.57**	**0.87**	**0.36**	**0.17**	**0.12**	**0.05**	**0.02**	**0.01**
500	***	15.77	**3.88**	**1.31**	**0.54**	**0.25**	**0.18**	**0.07**	**0.03**	**0.02**
600	***	22.10	**5.44**	**1.84**	**0.76**	**0.36**	**0.25**	**0.10**	**0.04**	**0.02**
700	***	***	**7.24**	**2.44**	**1.01**	**0.47**	**0.34**	**0.13**	**0.06**	**0.03**
800	***	***	**9.27**	**3.13**	**1.29**	**0.61**	**0.43**	**0.16**	**0.07**	**0.04**
900	***	***	11.54	**3.89**	**1.60**	**0.76**	**0.54**	**0.21**	**0.09**	**0.05**
1000	***	***	14.02	**4.73**	**1.95**	**0.92**	**0.66**	**0.25**	**0.11**	**0.06**
1100	***	***	16.73	**5.64**	**2.32**	**1.10**	**0.78**	**0.30**	**0.13**	**0.08**
1200	***	***	19.65	**6.63**	**2.73**	**1.29**	**0.92**	**0.35**	**0.16**	**0.09**
1300	***	***	***	7.69	**3.16**	**1.49**	**1.07**	**0.41**	**0.18**	**0.10**
1400	***	***	***	8.82	**3.63**	**1.71**	**1.22**	**0.46**	**0.21**	**0.12**
1500	***	***	***	10.02	**4.12**	**1.95**	**1.39**	**0.53**	**0.24**	**0.13**
1600	***	***	***	11.29	**4.65**	**2.19**	**1.57**	**0.60**	**0.27**	**0.15**
1700	***	***	***	12.63	**5.20**	**2.45**	**1.75**	**0.67**	**0.30**	**0.17**
1800	***	***	***	14.04	**5.78**	**2.73**	**1.95**	**0.74**	**0.33**	**0.19**
1900	***	***	***	15.52	6.39	**3.02**	**2.15**	**0.82**	**0.37**	**0.21**
2000	***	***	***	17.07	7.02	**3.32**	**2.37**	**0.90**	**0.40**	**0.23**
2100	***	***	***	18.68	7.69	**3.63**	**2.59**	**0.98**	**0.44**	**0.25**
2200	***	***	***	20.37	8.38	**3.96**	**2.83**	**1.07**	**0.48**	**0.27**
2300	***	***	***	***	9.10	**4.29**	**3.07**	**1.17**	**0.52**	**0.29**
2400	***	***	***	***	9.85	**4.65**	**3.32**	**1.26**	**0.57**	**0.32**
2500	***	***	***	***	10.62	5.01	**3.58**	**1.36**	**0.61**	**0.34**
2600	***	***	***	***	11.42	5.39	**3.85**	**1.46**	**0.66**	**0.37**
2700	***	***	***	***	12.25	5.78	**4.13**	**1.57**	**0.70**	**0.40**
2800	***	***	***	***	13.10	6.18	**4.42**	**1.68**	**0.75**	**0.42**
2900	***	***	***	***	13.98	6.60	4.71	**1.79**	**0.80**	**0.45**
3000	***	***	***	***	14.88	7.02	5.02	**1.91**	**0.86**	**0.48**
3100	***	***	***	***	15.81	7.46	5.33	**2.03**	**0.91**	**0.51**
3200	***	***	***	***	***	7.92	5.66	**2.15**	**0.96**	**0.54**
3300	***	***	***	***	***	8.38	5.99	**2.27**	**1.02**	**0.57**
3400	***	***	***	***	***	8.86	6.33	**2.40**	**1.08**	**0.61**
3500	***	***	***	***	***	9.35	6.68	**2.54**	**1.14**	**0.64**
3600	***	***	***	***	***	9.85	7.04	**2.67**	**1.20**	**0.68**
3700	***	***	***	***	***	10.36	7.40	**2.81**	**1.26**	**0.71**
3800	***	***	***	***	***	10.88	7.78	**2.95**	**1.33**	**0.75**
3900	***	***	***	***	***	11.42	8.16	**3.10**	**1.39**	**0.78**
4000	***	***	***	***	***	11.97	8.55	**3.25**	**1.46**	**0.82**
	4	6	8	10	12	14	15	18.3	21.57	24.27

(ACTUAL I.D. OF PIPE)

BASED ON HAZEN-WILLIAMS EQUATION
C = 150

(Flow rates below this line exceed 5.0 fps maximum)

Table CO7-7 Friction Loss in 50 PSI PVC Pipe (ft./1,000 ft.)

FLOW	PIPE SIZE (INCHES)									
GPM	4	6	8	10	12	14	15	18	21	24
100	5.77	0.81	0.20	0.07	0.03	0.01	0.01	0.00	0.00	0.00
200	20.82	2.92	0.73	0.25	0.10	0.05	0.03	0.01	0.01	0.00
300	44.12	6.18	1.55	0.52	0.21	0.10	0.07	0.03	0.01	0.01
400	***	10.53	2.64	0.89	0.37	0.17	0.12	0.05	0.02	0.01
500	***	15.92	3.99	1.34	0.55	0.26	0.19	0.08	0.03	0.02
600	***	22.32	5.59	1.88	0.77	0.36	0.26	0.11	0.05	0.03
700	***	***	7.43	2.51	1.03	0.48	0.35	0.14	0.06	0.04
800	***	***	9.52	3.21	1.32	0.61	0.45	0.18	0.08	0.05
900	***	***	11.83	3.99	1.64	0.76	0.55	0.22	0.10	0.06
1000	***	***	14.38	4.85	2.00	0.93	0.67	0.27	0.12	0.07
1100	***	***	17.16	5.79	2.38	1.11	0.80	0.33	0.15	0.08
1200	***	***	20.16	6.80	2.80	1.30	0.94	0.38	0.17	0.10
1300	***	***	***	7.89	3.24	1.51	1.09	0.44	0.20	0.11
1400	***	***	***	9.05	3.72	1.73	1.26	0.51	0.23	0.13
1500	***	***	***	10.28	4.23	1.97	1.43	0.58	0.26	0.15
1600	***	***	***	11.58	4.77	2.22	1.61	0.65	0.29	0.16
1700	***	***	***	12.96	5.33	2.48	1.80	0.73	0.33	0.18
1800	***	***	***	14.41	5.93	2.76	2.00	0.81	0.36	0.20
1900	***	***	***	15.92	6.55	3.05	2.21	0.89	0.40	0.23
2000	***	***	***	17.51	7.20	3.35	2.43	0.98	0.44	0.25
2100	***	***	***	19.17	7.88	3.67	2.66	1.08	0.48	0.27
2200	***	***	***	***	8.59	4.00	2.90	1.17	0.53	0.30
2300	***	***	***	***	9.33	4.35	3.15	1.27	0.57	0.32
2400	***	***	***	***	10.10	4.70	3.41	1.38	0.62	0.35
2500	***	***	***	***	10.89	5.07	3.67	1.49	0.67	0.38
2600	***	***	***	***	11.71	5.45	3.95	1.60	0.72	0.40
2700	***	***	***	***	12.56	5.85	4.24	1.71	0.77	0.43
2800	***	***	***	***	13.43	6.26	4.53	1.83	0.82	0.46
2900	***	***	***	***	14.33	6.68	4.84	1.96	0.88	0.49
3000	***	***	***	***	15.26	7.11	5.15	2.08	0.93	0.53
3100	***	***	***	***	16.22	7.55	5.47	2.21	0.99	0.56
3200	***	***	***	***	***	8.01	5.80	2.35	1.05	0.59
3300	***	***	***	***	***	8.48	6.14	2.49	1.12	0.63
3400	***	***	***	***	***	8.96	6.49	2.63	1.18	0.66
3500	***	***	***	***	***	9.46	6.85	2.77	1.24	0.70
3600	***	***	***	***	***	9.96	7.22	2.92	1.31	0.74
3700	***	***	***	***	***	10.48	7.59	3.07	1.38	0.78
3800	***	***	***	***	***	11.01	7.98	3.23	1.45	0.82
3900	***	***	***	***	***	11.56	8.37	3.39	1.52	0.86
4000	***	***	***	***	***	12.11	8.77	3.55	1.59	0.90
	4	5.988	7.958	9.948	11.94	13.93	14.92	18.24	21.18	23.83

(ACTUAL I.D. OF PIPE)

BASED ON HAZEN-WILLIAMS EQUATION
C = 150

NOTE: Pipe (15-inch and greater) only comes in 80 psi
(Flow rates below this line exceed 5.0 fps maximum)

Table CO7-8 Friction Loss in Gated PVC Pipe (ft./1,000 ft.)

FLOW	PIPE SIZE (INCHES)			
GPM	6	8	10	12
100	**0.98**	**0.23**	**0.07**	**0.03**
200	**3.53**	**0.83**	**0.27**	**0.11**
300	**7.47**	**1.75**	**0.57**	**0.23**
400	**12.73**	**2.98**	**0.98**	**0.39**
500	**19.24**	**4.51**	**1.47**	**0.59**
600	26.96	**6.31**	**2.07**	**0.83**
700	35.87	**8.40**	**2.75**	**1.11**
800	***	**10.76**	**3.52**	**1.42**
900	***	**13.38**	**4.38**	**1.77**
1000	***	**16.26**	**5.32**	**2.15**
1100	***	19.40	**6.35**	**2.56**
1200	***	22.79	**7.46**	**3.01**
1300	***	26.44	**8.65**	**3.49**
1400	***	30.33	**9.93**	**4.00**
1500	***	***	**11.28**	**4.55**
1600	***	***	**12.71**	**5.13**
1700	***	***	14.22	**5.74**
1800	***	***	15.81	**6.38**
1900	***	***	17.47	**7.05**
2000	***	***	19.21	**7.75**
2100	***	***	21.03	**8.48**
2200	***	***	22.92	**9.25**
2300	***	***	24.89	**10.04**
2400	***	***	26.93	10.86
2500	***	***	29.05	11.72
2600	***	***	31.23	12.60
2700	***	***	***	13.51
2800	***	***	***	14.45
2900	***	***	***	15.42
3000	***	***	***	16.42
	5.76	7.76	9.76	11.76

(ACTUAL I.D. OF PIPE)

BASED ON HAZEN-WILLIAMS EQUATION

C = 150

(Flow rates below this line exceed 7.0 fps maximum)

Table CO7-9 Friction Loss in Gated Aluminum Pipe (ft./1,000 ft.)

FLOW GPM	PIPE SIZE (INCHES) 4	6	8	10	12
100	**8.51**	**1.13**	**0.27**	**0.09**	**0.04**
200	**30.70**	**4.09**	**0.99**	**0.33**	**0.14**
300	65.05	**8.66**	**2.09**	**0.70**	**0.29**
400	***	**14.76**	**3.56**	**1.19**	**0.49**
500	***	**22.31**	**5.38**	**1.79**	**0.74**
600	***	**31.27**	**7.54**	**2.51**	**1.03**
700	***	41.60	**10.04**	**3.34**	**1.37**
800	***	***	**12.85**	**4.28**	**1.76**
900	***	***	**15.99**	**5.33**	**2.19**
1000	***	***	**19.43**	**6.47**	**2.66**
1100	***	***	23.18	**7.72**	**3.17**
1200	***	***	27.23	**9.07**	**3.73**
1300	***	***	31.58	**10.52**	**4.32**
1400	***	***	36.23	**12.07**	**4.96**
1500	***	***	41.17	**13.72**	**5.63**
1600	***	***	***	**15.46**	**6.35**
1700	***	***	***	17.29	**7.10**
1800	***	***	***	19.22	**7.90**
1900	***	***	***	21.25	**8.73**
2000	***	***	***	23.37	**9.60**
2100	***	***	***	25.58	**10.51**
2200	***	***	***	27.88	**11.45**
2300	***	***	***	30.27	**12.43**
2400	***	***	***	32.75	**13.45**
2500	***	***	***	35.32	14.51
2600	***	***	***	37.98	15.60
2700	***	***	***	***	16.73
2800	***	***	***	***	17.90
2900	***	***	***	***	19.10
3000	***	***	***	***	20.34
	3.9	5.9	7.9	9.9	11.884

(ACTUAL I.D. OF PIPE)

BASED ON HAZEN-WILLIAMS EQUATION

C = 130

(Flow rates below this line exceed 7.0 fps maximum)

Table CO7-10 Head Loss Through Alfalfa Valves and Portable Hydrants

	Valve and Riser				Portable Hydrant			
FLOW	Valve Size (in.)				Outlet Size (in.)			
(GPM)	8	10	12	14	6	8	10	12
400	0.3	0.1	0.1	0.0	0.3	0.1	0.0	0.0
500	0.4	0.2	0.1	0.0	0.5	0.2	0.1	0.0
600	0.6	0.3	0.1	0.1	0.7	0.2	0.1	0.0
700	0.9	0.4	0.2	0.1	1.0	0.3	0.1	0.1
800	1.1	0.5	0.2	0.1	1.3	0.4	0.2	0.1
900	1.4	0.6	0.3	0.2	1.6	0.5	0.2	0.1
1000	1.8	0.7	0.3	0.2	2.0	0.6	0.3	0.1
1100	2.1	0.9	0.4	0.2	2.4	0.8	0.3	0.2
1200	2.5	1.0	0.5	0.3	2.9	0.9	0.4	0.2
1300	3.0	1.2	0.6	0.3	3.4	1.1	0.4	0.2
1400	3.4	1.4	0.7	0.4	3.9	1.2	0.5	0.2
1500	3.9	1.6	0.8	0.4	4.5	1.4	0.6	0.3
1600	4.5	1.8	0.9	0.5	5.1	1.6	0.7	0.3
1700	5.1	2.1	1.0	0.5	5.8	1.8	0.7	0.4
1800	5.7	2.3	1.1	0.6	6.5	2.1	0.8	0.4
1900	6.3	2.6	1.3	0.7	7.2	2.3	0.9	0.5
2000	7.0	2.9	1.4	0.7	8.0	2.5	1.0	0.5
2100	7.7	3.2	1.5	0.8	8.8	2.8	1.1	0.6
2200	8.5	3.5	1.7	0.9	9.7	3.1	1.3	0.6
2300	9.3	3.8	1.8	1.0	10.6	3.4	1.4	0.7
2400	10.1	4.1	2.0	1.1	11.5	3.6	1.5	0.7
2500	11.0	4.5	2.2	1.2	12.5	4.0	1.6	0.8
2600	11.9	4.9	2.3	1.3	13.5	4.3	1.8	0.8
2700	12.8	5.2	2.5	1.4	14.6	4.6	1.9	0.9
2800	13.8	5.6	2.7	1.5	15.7	5.0	2.0	1.0
2900	14.8	6.0	2.9	1.6	16.8	5.3	2.2	1.1
3000	15.8	6.5	3.1	1.7	18.0	5.7	2.3	1.1

(3) Equations used to develop pipe friction loss tables:

Hazen-Williams Equation:

$$h_f = (1000)\left[\frac{(3.552)(Q)}{(C)(d^{2.63})}\right]^{1/0.54}$$

Manning's Equation:

$$h_f = (1000)\left[\frac{(3.631)(Q)(n)}{(d)^{8/3}}\right]^{2}$$

Where:

h_f = friction loss, ft./1000 ft.

Q = flow rate, gpm

d = inside pipe diameter, inches

C = Hazen-Williams roughness coefficient

n = Manning's roughness coefficient

(4) Equations used to develop head loss table

For alfalfa valves and risers: $h = \frac{2.77V^2}{2g}$

For portable hydrants: $h = \frac{V^2}{2g}$

Where:

h = head loss, ft.

V = flow velocity, ft./sec.

g = 32.2 ft./sec.^{2}

(d) Design Summary for Low Pressure, Underground, Plastic Pipeline - Code 430EE

This summary covers the major criteria for this practice. Refer to the standard and specifications for further details.

(1) Velocity

Flow Rate at Which a Velocity of 5 ft./sec. Occurs

Nominal Pipe Dia. (Inches)	Flow Rate (GPM)
6	441
8	783
10	1224
12	1763
14	2399
15	2754

(2) Stands

Pump stand or "dogleg" to be located at the outlet of the pump discharge pipe. For a closed system, the minimum diameter of stand or "dogleg" is the pipe diameter.

(3) Check Valves

Install check valves between the pump discharge and the stand.

(4) Pressure Relief Valves

Install on the pump stand or level portion of the "dogleg."

Capacity of Various Pressure Relief Valves, in GPM, at 32.5 PSI, Set to Open at 22 PSI*

Valve Size	Waterman			Fresno	
(Inches)	AA-96C	AA-9	AA-6	PR900	PR600
3	675	---	60	630	165
4	1030	---	120	1045	---
6	---	1580	---	1550	---

* From manufacturer's test data. Refer to manufacturer's literature for PRV capacity for pipelines with working pressures greater than 22 psi.

(5) Air and Vacuum Release Valves (Air Relief Valves)

Minimum Size of Air & Vacuum Release Valve Installation*

ARV Size (Inches)	Nominal Pipe Dia. (Inches)
1-1/2	4
2 & 2-1/2	6 & 8
3	10
4	12, 14, 15

* Based on manufacturer's data for Waterman AV-150 and size table contained in 430EE standard. Other valves may be used subject to meeting opening-size requirements contained in the 430EE standard.

Install air and vacuum release valves at the following locations:

1. Pump stand or "dogleg"
2. Any high point (summit) in the pipeline
3. End of pipeline
4. On either side of any in-line control device, such as a hub end gate or line gate valve
5. Wherever there are changes in pipeline grade in a downward direction of flow greater than 10 degrees (18% slope).

(6) Outlets and Appurtenances

Install a sufficient number of risers and alfalfa valves to facilitate operation of gated pipe, irrigation of borders, or to deliver water to other specific points. Install line gate valves or hub end gates as required to manage water delivery in the system.

(e) Irrigation Land Leveling - Code 464

This section summarizes design criteria and methods for irrigation land leveling. For more detailed information, consult the following references:

- Colorado Supplements to this handbook (National Engineering Handbook Part 652, Irrigation Guide)
- Colorado Standard and Specifications for Irrigation Land Leveling - Code 464
- National Engineering Handbook, Section 15, Irrigation, Chapter 12, Land Leveling

(1) Design Criteria Summary

(i) Design Data--The data used for design should be taken from a detailed grid survey.

(ii) Irrigation System Design and Operation--The land leveling design must allow for practical and efficient operation and be compatible with the irrigation development plan. Planning and design criteria listed in Part 1 of the Colorado Irrigation Guide is used in plan development and should be reflected in the land leveling design. For designs in areas where there is not significant irrigation experience or where special conditions exist, refer also to Parts 2 and 3 of the Irrigation Guide. These sections will indicate whether the desired crops can be feasibly irrigated and whether the soils are suitable for gravity irrigation. Refer to Part 4 of the Irrigation Guide when establishing field layout. Field dimensions should be compatible with the application rate, length of run, and slope limitations contained in Part 4.

(iii) Physical Design Criteria--Refer to the 464 Standard for criteria relating to field grade, drainage, and elevation control for water distribution systems.

(iv) Design Method--One of the following methods is generally used to design the leveling plan:

- Plane Method - This method results in a field surface with a uniform downfield slope and cross slope. The centroid of the area is first found and a plane is passed through that point at an elevation equal to the average elevation of the field. The plane is then lowered slightly to provide more excavation than fill (i.e. a cut-fill ratio greater than 1.0). Using this method with manual computation is quite tedious and time consuming for large fields. The PC version of the Plane Surface Design computer program may be used to speed computations. This program is best suited to fields with a limited number of fringe areas.

- Profile Method - Using this method, the designer works with profiles of grid lines rather than individual grid elevations. This is a trial- and-error method of adjusting grades on plotted profiles until all design criteria are satisfied. The profile grades are then transferred to the grid map, design elevations computed, and the resulting leveling map checked for adherence to forward slope and cross slope criteria. Also, earthwork computations are made to determine if the cut-fill ratio is satisfactory.
- Plan-Inspection Method - This is a trial-and-error method that relies heavily upon the knowledge, experience and judgement of the designer. When using this method, contours are generally plotted on a copy of the grid map. Contour interval will depend upon the topography and desired field slopes. On nearly level fields, a contour interval of 0.5 foot may be desirable. For design slopes of 0.5-1.0 percent, contour intervals of 1.0 foot are generally satisfactory. Using the contours as indicators, areas of relatively uniform slope are assigned trial elevations or grades. The contours may also indicate areas where variable grade may be desirable. Where extreme elevation differences occur, contours may be used to guide placement of bench areas. The trial elevations assigned to the grid points are then checked for conformance to grade criteria. Earthwork computations are performed to determine is the cut-fill ratio is satisfactory. Also, extreme values of cut and fill should be inspected to determine if they are feasible, as should haul distances.
- Contour Adjustment Method - This method consists of trial-and-error adjustment of contour lines drawn on the grid map. Design elevations at the grid points are determined by interpolating between the design or adjusted contours. Like the other methods, cuts and fills are determined by comparing the design elevations to the original elevations, grades are checked, and earthwork computations are performed. This method is best adapted to fields where uniform cross slope is feasible, and for contour furrow irrigation systems.

(v) Earthwork Calculations--A number of methods may be used to estimate earthwork volumes during the trial-and-error phase of the design. All final design quantities, however, are to be computed using the four-point method. The following explanation of the four-point method was taken from Chapter 12, Land Leveling, of NEH-15.

(2) Design Documentation and Plans

Figure CO7-6 illustrates the format typically used to develop design documentation and plans.

Where:

V = Volume in cubic feet
L = Perpendicular distance between end planes in feet
A_1 = Area of one end plane in square feet
A_2 = Area of other end plane in square feet
A_m = Area in middle section parallel to end planes in square feet

The use of this formula is laborious, and approximate methods are commonly used.

The four-point method--The four-point method is based on the formula:

$$V_c = \frac{L^2(H_c^2)}{108(H_c + H_f)}$$

and

$$Vf = \frac{L^2(H_f^2)}{108(H_c + H_f)}$$

Where:

V_c = Volume of cut in cubic yards
V_f = Volume of fill in cubic yards
L = Grid spacing in feet
H_c = Sum of cuts on four corners of a grid square in feet
H_f = Sum of fills on four corners of a grid square in feet

Figure CO7-6 Format for Listing Elevations, Cuts, and Fills on Land Leveling Grid Maps

Normal Field Layout
(100 ft. x 100 ft. grid)

98	2	98	5	97	7	97	1	- Original elevation
98	2	98	0	97	8	97	6	- Planned or design elevation
0	0	-0	5	+0	1	+0	5	- Cut (-) or fill (+) or use C = cut and F = fill
98	1	98	6	97	9	96	9	
98	2	98	0	97	8	97	6	
+0	1	-0	6	-0	1	+0	7	

Optional: Record as-built (final checkout) elevations above original elevations.

Horizontal Bench Line

To denote elevations on either side of a bench boundary shown horizontally on the leveling map:

+0.6	+0.1	+0.7	+1.1	- Cut (-) or fill (+)
98.8	98.6	98.4	98.2	- Planned or design elevation
98.2	98.5	97.7	97.1	- Original elevation
97.8	97.6	97.4	97.2	- Planned or design elevation
-0.4	-0.9	-0.3	+0.1	- Cut (-) or fill (+)

Optional: Record as-built (final checkout) elevations vertically along the side of the planned and original elevations.

Vertical Bench Line

To denote elevations on either side of a bench boundary shown vertically on the leveling map:

98.5	97	7	- Original elevation
98.0	98.0	97.0	- Planned or design elevation
-0.5	+0.3	-0.7	- Cut (-) or fill (+)
98.6	97	9	
97.8	97.8	96.8	
-0.8	-0.1	-1.1	
98.2	96	5	
97.6	97.6	96.6	
-0.6	+1.1	+0.1	

Optional: Record as-built (final checkout) elevations above original elevations.

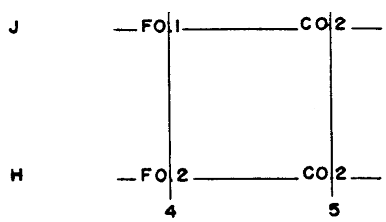
Color Coding System

The following color coding system has been used to develop land leveling grid maps:

Original elevation - black ink
Planned or design elevation - pencil
As-built or final check elevation - green

Cut - red
Fill - blue

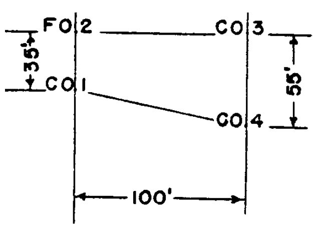
Using the formula, the volume of cut and fill in each grid square can be ascertained and the totals for the field obtained. Table CO7-11 provides a rapid method for determining the excavation and fill in a 100-foot grid square. Let us examine the following grid:



The sum of the cuts are 0.4 and the sum of the fills are 0.3. Since the square is 100 feet to a side, the volume of earthwork as given by Table CO7-11 is as follows:

Excavation	21 cubic yards
Fill	12 cubic yards

The following methods have been found satisfactory for computing the volumes in other than square grids. For grids with four corners:



$$\text{Area grid} = \frac{35 + 55}{2} \times 100 = 4{,}500 \text{ square feet}$$

Area in 100 x 100 grid = 10,000 square feet

From Table CO7-11 for a 100 x 100 grid:

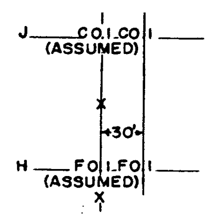
Cut = 59 cubic yards and fill = 4 cubic yards

For the reduced grid:

$$\text{Excavation} = 59 \times \frac{4{,}500}{10{,}000} \text{ (or .45)} = 27 \text{ cubic yards}$$

Fill = 4 x .45 = 2 cubic yards

Correct use of the four-point method requires that the cut or fill be known at the outside edges of the field. In practice, however, stakes are seldom placed in the fence lines, and usually it is satisfactory to assume that the cut in the fence line is identical to that of the nearest stake. Where abnormal conditions exist, plus stakes should be used. For the grid shown below, the following calculation was made:



Area in grid = 30 x 100 = 3,000 square feet

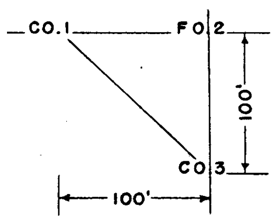
From Table CO7-11:

C = 9 cubic yards
F = 9 cubic yards

$$\text{Corrected Volume} = \frac{3{,}000}{10{,}000} \text{ (or .3)} \times 9 = 3 \text{ cubic yards}$$

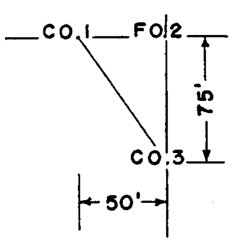
C = 3
F = 3

For a triangular area, the sum of the three corners can be taken and the values in the table reduced to two-thirds. Thus,



Sum of cuts = 0.4
Sum of fills = 0.2
From Table CO7-11, C = 25 and F = 6
Excavation = 2/3 x 25 = 17 cubic yards
Fill = 2/3 x 6 = 4 cubic yards

When triangular areas not 100 feet on each side are encountered, the volumes may be determined by further reducing the tabular values in proportion to the product of the length of the sides



Sum of cuts = 0.4
Sum of fills = 0.2
Excavation = $\frac{50 \times 75}{100 \times 100}$ x (or .25) x 25 = 6 cu. yds.
Fill = .25 x 6 = 2 cubic yards

The four-point method is rapid and gives an accuracy comparable to the accuracy of the original survey.

Table CO7-11 Earthwork Quantities in Cubic Yards with 100-Foot Land Leveling Grid

EARTHWORK QUANTITIES IN CUBIC YARDS WITH ONE HUNDRED FOOT LAND LEVELING GRID

SUM OF CUTS ON FOUR CORNERS (columns); SUM OF FILLS ON FOUR CORNERS (rows)

Sum of fills		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
0.0	CUT	0	9	19	28	37	46	56	65	74	83	93	102	111	120	130	139	148	157	167	176	185	194	204	213	222	232	241	250	259	269	278
	FILL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	CUT	0	5	12	21	30	39	48	57	66	75	84	93	103	112	121	130	139	149	158	167	176	186	195	204	213	223	232	241	250	260	269
	FILL	9	5	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
0.2	CUT	0	3	9	17	25	33	42	50	59	68	77	86	95	104	113	123	132	141	150	159	168	178	187	196	205	214	224	233	242	251	260
	FILL	19	12	9	7	6	5	5	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1
0.3	CUT	0	2	7	14	21	29	37	45	54	63	71	80	89	98	107	116	125	134	143	152	161	170	179	188	198	207	216	225	234	243	253
	FILL	28	21	17	14	12	10	9	8	8	7	6	6	6	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3
0.4	CUT	0	2	6	12	19	26	33	41	49	58	66	75	83	92	101	110	119	127	136	145	154	163	172	181	191	200	209	218	227	236	245
	FILL	37	30	25	21	19	17	15	14	12	11	11	10	9	9	8	8	7	7	7	6	6	6	6	6	5	5	5	5	5	5	4
0.5	CUT	0	2	5	10	17	23	30	38	46	54	62	70	78	87	96	104	113	122	130	139	148	157	166	175	184	193	202	211	220	229	239
	FILL	46	39	33	29	26	23	21	19	18	17	15	15	14	13	12	12	11	11	10	10	9	9	9	8	8	8	8	7	7	7	7
0.6	CUT	0	1	5	9	15	21	28	35	42	50	58	66	74	82	91	99	108	116	125	134	142	151	160	169	178	187	196	205	214	223	232
	FILL	56	48	42	37	33	30	28	26	24	22	21	20	19	18	17	16	15	15	14	13	13	12	12	12	11	11	10	10	10	10	9
0.7	CUT	0	1	4	8	14	19	26	32	40	47	55	62	70	78	86	95	103	112	120	129	137	146	155	163	172	181	190	199	208	216	225
	FILL	65	57	50	45	41	38	35	32	30	28	27	25	24	23	22	21	20	19	18	18	17	16	16	15	15	14	14	13	13	13	12
0.8	CUT	0	1	4	8	12	18	24	30	37	44	51	59	67	75	83	91	99	107	115	124	132	141	149	158	167	175	184	193	202	211	219
	FILL	74	66	59	54	49	46	42	40	37	35	33	31	30	28	27	26	25	24	23	22	21	20	20	19	19	18	17	17	17	16	16
0.9	CUT	0	1	3	7	11	17	22	28	35	42	49	56	64	71	79	87	95	103	111	119	128	136	145	153	162	170	179	188	196	205	214
	FILL	83	75	68	63	58	54	50	47	44	42	40	38	36	34	33	31	30	29	28	27	26	25	24	23	23	22	21	21	20	20	19
1.0	CUT	0	1	3	6	11	15	21	27	33	40	46	53	61	68	76	83	91	99	107	115	124	132	140	148	157	165	174	183	191	200	208
	FILL	93	84	77	71	66	62	58	55	51	49	46	44	42	40	39	37	36	34	33	32	31	30	29	28	27	27	26	25	24	24	23
1.1	CUT	0	1	3	6	10	15	20	25	31	38	44	51	58	65	73	80	88	96	104	111	120	128	136	144	152	161	169	179	186	195	203
	FILL	102	93	86	80	75	70	66	62	59	56	53	51	49	47	45	43	42	40	39	37	36	35	34	33	32	31	30	30	29	28	27
1.2	CUT	0	1	3	6	9	14	19	24	30	36	42	49	56	63	70	77	85	92	100	107	116	124	132	140	148	156	165	173	182	190	199
	FILL	111	103	95	89	83	78	74	70	67	64	61	58	56	53	51	49	48	46	44	43	42	40	39	38	37	36	35	34	33	33	32
1.3	CUT	0	1	3	5	9	13	18	23	28	34	40	47	53	60	67	74	82	89	97	104	112	120	128	136	144	152	161	169	177	185	194
	FILL	120	112	104	98	92	87	82	78	75	71	68	65	63	60	58	56	54	52	51	49	47	46	45	44	42	41	40	39	38	37	36
1.4	CUT	0	1	2	5	8	12	17	22	27	33	39	45	51	58	65	72	79	86	94	101	109	117	125	132	140	148	157	165	173	181	189
	FILL	130	121	113	107	101	96	91	86	83	79	76	73	70	67	65	63	61	59	57	55	53	52	50	49	48	47	45	44	43	42	41
1.5	CUT	0	1	2	5	8	12	16	21	26	31	37	43	49	56	63	69	77	84	91	98	106	113	121	129	137	145	153	161	169	177	185
	FILL	139	130	123	116	110	104	99	95	91	87	83	80	77	74	72	69	67	65	63	61	60	58	56	55	53	52	51	50	48	47	46
1.6	CUT	0	1	2	4	7	11	15	20	25	30	36	42	48	54	61	67	74	81	88	96	103	110	118	126	133	141	149	157	165	173	181
	FILL	148	139	132	125	119	113	108	103	99	95	91	88	85	82	79	77	74	72	70	68	66	64	62	61	59	58	57	55	54	53	52
1.7	CUT	0	1	2	4	7	11	15	19	24	29	34	40	46	52	59	65	72	79	86	93	100	108	115	123	130	138	146	153	161	169	177
	FILL	157	149	141	134	127	122	116	112	107	103	99	96	92	89	86	84	81	79	77	74	72	70	69	67	65	64	62	61	60	58	57
1.8	CUT	0	1	2	4	7	10	14	19	23	28	33	39	44	51	57	63	70	77	83	90	98	105	112	120	127	135	142	150	158	156	174
	FILL	167	158	150	143	136	130	125	120	115	111	107	104	100	97	94	91	88	86	83	81	79	77	75	73	71	70	68	67	65	64	63
1.9	CUT	0	1	2	4	6	10	13	18	22	27	32	37	43	49	55	61	68	74	81	88	95	102	109	117	124	132	139	147	155	162	170
	FILL	176	167	159	152	145	139	134	129	124	119	115	111	108	105	101	98	96	93	90	88	86	84	82	80	78	76	74	73	71	70	68
2.0	CUT	0	0	2	4	6	9	13	17	21	26	31	36	42	47	53	60	66	72	79	86	93	100	107	114	121	129	136	144	151	159	167
	FILL	185	176	169	161	154	148	142	137	132	128	124	120	116	112	109	106	103	100	98	95	93	90	88	86	84	82	81	79	77	76	74
2.1	CUT	0	0	2	4	6	9	12	16	20	25	30	35	40	46	52	58	64	70	77	84	90	97	104	111	119	126	133	141	148	156	163
	FILL	194	186	178	170	163	157	151	146	141	136	132	128	124	120	117	113	110	108	105	102	100	97	95	93	91	89	87	85	83	82	80
2.2	CUT	0	0	2	3	6	9	12	16	20	24	29	34	39	45	50	56	62	69	75	82	88	95	102	109	116	123	130	138	145	153	160
	FILL	204	195	187	179	172	166	160	155	149	145	140	136	132	128	125	121	118	115	112	109	107	104	102	100	97	95	93	92	90	88	86
2.3	CUT	0	0	2	3	6	8	12	15	19	23	28	33	38	44	49	55	61	67	73	80	86	93	100	107	114	121	128	135	142	150	157
	FILL	213	204	196	188	181	175	169	163	158	153	148	144	140	136	132	129	126	123	120	117	114	111	109	107	104	102	100	98	96	94	92
2.4	CUT	0	0	1	3	5	8	11	15	19	23	27	32	37	42	48	53	59	65	71	78	84	91	97	104	111	118	125	132	140	147	154
	FILL	222	213	205	198	191	184	178	172	167	162	157	152	148	144	140	137	133	130	127	124	121	119	116	114	111	109	107	105	103	101	99
2.5	CUT	0	0	1	3	5	8	11	14	18	22	27	31	36	41	47	52	58	64	70	76	82	89	95	102	109	116	123	130	137	144	152
	FILL	232	223	214	207	200	193	187	181	175	170	165	161	156	152	148	145	141	138	135	132	129	126	123	121	118	116	114	111	109	107	105
2.6	CUT	0	0	1	3	5	8	10	14	17	21	26	30	35	40	45	51	57	62	68	74	81	87	93	100	107	114	120	127	135	142	149
	FILL	241	232	224	216	209	202	196	190	184	179	174	169	165	161	157	153	149	146	142	139	136	133	130	128	125	123	120	118	116	114	112
2.7	CUT	0	0	1	3	5	7	10	13	17	21	25	30	34	39	44	50	55	61	67	73	79	85	92	98	105	111	118	125	132	139	146
	FILL	250	241	233	225	218	211	205	199	193	188	183	178	173	169	165	161	157	153	150	147	144	141	138	135	132	130	127	125	123	121	118
2.8	CUT	0	0	1	3	5	7	10	13	17	20	24	29	33	38	43	48	54	60	65	71	77	83	90	96	103	109	116	123	130	137	144
	FILL	259	250	242	234	227	220	214	208	202	196	191	186	182	177	173	169	165	161	158	155	151	148	145	142	140	137	135	132	130	127	125
2.9	CUT	0	0	1	3	5	7	10	13	16	20	24	28	33	37	42	47	53	58	64	70	76	82	88	94	101	107	114	121	127	134	141
	FILL	269	260	251	243	236	229	223	216	211	205	200	195	190	185	181	177	173	169	166	162	159	156	153	150	147	144	142	139	137	134	132
3.0	CUT	0	0	1	3	4	7	9	12	16	19	23	27	32	36	41	46	52	57	63	68	74	80	86	92	99	105	112	118	125	132	139
	FILL	278	269	260	253	245	238	232	225	219	214	208	203	199	194	189	185	181	177	174	170	167	163	160	157	154	152	149	146	144	141	139

Sum of fills		3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0
0.0	CUT	287	296	306	315	324	333	343	352	361	370	380	389	398	407	417	426	435	444	454	463	472	482	491	500	509	519	528	537	546	556
	FILL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	CUT	278	287	297	306	315	324	334	343	352	361	371	380	389	398	408	417	426	435	445	454	463	472	482	491	500	509	519	528	537	546
	FILL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.2	CUT	270	279	288	297	307	316	325	334	343	353	362	370	380	390	399	408	417	427	436	445	454	464	473	482	491	501	510	519	528	538
	FILL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.3	CUT	262	271	280	289	299	308	317	326	335	345	354	363	372	381	391	400	409	418	428	437	446	455	464	474	483	492	501	511	520	529
	FILL	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1
0.4	CUT	254	263	273	282	291	300	309	318	328	337	346	355	364	373	383	392	401	410	419	429	438	447	456	466	475	484	493	502	512	521
	FILL	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2
0.5	CUT	247	256	265	274	284	293	302	311	320	329	338	348	357	366	375	384	393	403	412	421	430	439	448	458	467	476	485	494	504	513
	FILL	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4	4	4	4	4	4
0.6	CUT	241	250	259	268	277	286	295	304	313	322	331	341	349	359	368	377	386	395	404	413	423	432	441	450	459	468	478	487	496	505
	FILL	9	9	9	8	8	8	8	8	7	7	7	7	7	7	7	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5
0.7	CUT	234	243	252	261	270	279	288	297	306	315	324	334	343	352	361	369	378	388	397	406	415	424	433	443	452	461	470	479	488	498
	FILL	12	12	11	11	11	11	10	10	10	10	10	9	9	9	9	9	8	8	8	8	8	8	8	7	7	7	7	7	7	7
0.8	CUT	228	237	246	255	264	273	282	291	300	309	318	327	335	345	354	363	372	381	390	399	408	417	426	436	445	454	463	472	481	490
	FILL	15	15	15	14	14	14	13	13	13	12	12	12	12	11	11	11	11	11	10	10	10	10	10	10	9	9	9	9	9	9
0.9	CUT	223	231	240	249	258	267	276	285	293	302	311	320	329	338	347	357	365	374	383	392	401	410	419	429	438	447	456	465	474	483
	FILL	19	18	18	17	17	17	16	16	16	15	15	15	14	14	14	14	13	13	13	13	13	12	12	12	12	12	11	11	11	11
1.0	CUT	217	226	235	243	252	261	270	279	288	296	305	314	323	332	341	350	359	368	377	386	395	404	413	422	431	440	449	458	467	476
	FILL	23	22	22	21	21	20	20	19	19	19	18	18	18	17	17	17	16	16	16	15	15	15	15	15	14	14	14	14	13	13
1.1	CUT	212	221	229	238	247	255	264	273	282	291	299	308	317	326	335	344	353	362	371	379	388	397	406	415	424	433	442	451	460	469
	FILL	27	26	26	25	24	24	23	23	22	22	22	21	21	20	20	20	19	19	19	18	18	18	18	17	17	17	17	16	16	16
1.2	CUT	207	216	224	233	241	250	259	267	276	285	294	303	311	320	329	338	347	356	364	373	382	391	400	409	418	427	436	445	454	463
	FILL	31	30	30	29	28	28	27	27	26	26	25	25	24	24	23	23	23	22	22	22	21	21	21	21	20	20	19	19	19	19
1.3	CUT	202	211	219	228	236	245	254	262	271	280	288	298	306	314	323	332	341	350	359	367	376	385	394	403	412	421	430	439	448	457
	FILL	36	35	34	33	33	32	31	31	30	30	29	29	28	28	27	27	26	26	25	25	25	24	24	23	23	23	22	22	22	21
1.4	CUT	198	206	215	223	232	240	249	257	266	274	283	292	300	309	318	326	335	344	353	362	371	379	388	397	406	415	424	433	442	450
	FILL	40	40	39	38	37	36	36	35	34	34	33	32	32	31	31	30	30	29	29	28	28	28	27	27	26	26	26	25	25	25
1.5	CUT	194	202	210	219	227	235	244	252	261	269	278	287	295	304	313	321	330	339	347	356	365	374	382	391	400	409	418	427	436	444
	FILL	45	44	43	43	42	41	40	39	39	38	37	37	36	35	35	34	34	33	33	32	32	31	31	30	30	29	29	29	28	28
1.6	CUT	189	198	206	214	223	231	239	248	256	265	273	282	290	299	307	316	325	333	342	351	359	368	377	385	394	403	412	421	430	439
	FILL	50	49	48	47	47	46	45	44	43	42	42	41	40	40	39	38	38	37	37	36	35	35	34	34	33	33	33	32	32	31
1.7	CUT	185	194	202	210	218	226	235	243	251	260	268	277	285	294	302	311	320	328	337	346	354	363	372	380	389	398	407	415	424	433
	FILL	56	55	54	53	52	51	50	49	48	47	46	45	45	44	43	43	42	41	41	40	39	39	38	38	37	37	36	36	35	35
1.8	CUT	182	190	198	206	214	222	231	239	247	255	264	273	281	289	298	306	315	323	332	340	349	358	366	375	384	392	401	410	419	427
	FILL	61	60	59	58	57	56	55	54	53	52	51	50	49	48	48	47	46	46	45	44	44	43	42	42	41	41	40	40	39	39
1.9	CUT	178	186	194	202	210	218	226	235	243	251	259	268	276	285	293	301	310	318	327	336	344	353	361	370	378	387	396	404	413	422
	FILL	67	66	64	63	62	61	60	59	58	57	56	55	54	53	52	51	51	50	49	48	48	47	46	46	45	45	44	43	43	42
2.0	CUT	175	182	190	198	206	214	222	231	239	247	255	264	271	280	288	296	305	314	322	331	339	348	356	365	373	382	391	399	408	417
	FILL	73	71	70	69	67	66	65	64	63	62	61	60	59	58	57	56	55	55	54	53	52	51	51	50	49	49	48	48	47	46
2.1	CUT	171	180	187	195	203	211	219	227	235	243	251	260	267	275	284	292	301	309	318	326	334	343	351	360	369	377	386	394	403	412
	FILL	79	77	76	74	73	72	70	69	68	67	66	65	64	63	62	61	60	59	58	58	57	56	55	54	54	53	52	52	51	50
2.2	CUT	168	176	183	191	199	207	215	223	231	239	247	256	265	272	280	288	296	305	313	322	330	338	347	355	364	372	381	389	398	407
	FILL	85	83	82	80	79	77	76	75	74	72	71	70	69	68	67	66	65	64	63	62	61	61	60	59	58	58	57	56	55	55
2.3	CUT	165	172	180	188	196	203	211	219	227	235	243	252	259	268	276	284	292	301	309	317	325	334	342	351	359	368	376	385	393	402
	FILL	91	89	87	86	84	83	82	80	79	78	77	75	74	73	72	71	70	69	68	67	66	65	64	64	63	62	61	61	60	59
2.4	CUT	162	169	177	185	192	200	208	216	224	232	239	248	256	264	272	280	288	296	305	313	321	329	338	346	355	363	371	380	388	397
	FILL	97	95	94	92	90	89	87	86	85	83	82	81	80	78	77	76	75	74	73	72	71	70	69	68	68	67	66	65	64	64
2.5	CUT	159	166	174	181	189	197	204	212	220	228	236	244	252	260	268	276	284	292	300	309	317	325	333	342	350	358	367	375	384	392
	FILL	103	102	100	98	96	95	93	92	90	89	88	86	85	84	83	82	80	79	78	77	76	75	74	73	72	71	71	70	69	68
2.6	CUT	156	163	171	178	186	194	201	209	217	225	232	241	247	256	264	272	280	288	296	305	313	321	329	338	346	354	362	371	379	388
	FILL	110	108	106	104	103	101	99	98	96	95	93	92	91	89	88	87	86	85	84	82	81	80	79	78	77	76	75	75	74	73
2.7	CUT	153	161	168	176	183	191	198	206	213	221	229	237	244	253	260	268	276	284	293	301	309	317	325	333	342	350	358	366	375	383
	FILL	116	114	113	111	109	107	106	104	102	101	99	98	96	95	94	93	91	90	88	88	87	85	84	83	82	81	80	79	79	78
2.8	CUT	151	158	165	173	180	188	195	203	210	218	226	233	241	249	257	264	273	281	289	297	305	313	321	329	337	346	354	362	371	379
	FILL	123	121	119	117	115	113	112	110	108	107	105	104	102	101	99	98	97	96	94	93	92	91	90	89	88	86	85	84	83	83
2.9	CUT	148	155	163	170	177	185	192	200	207	215	222	231	238	246	253	261	269	277	285	293	301	309	317	325	333	342	350	358	366	374
	FILL	130	128	126	124	122	120	118	116	115	113	111	110	108	107	105	104	103	101	100	99	97	96	95	94	93	92	91	90	89	88
3.0	CUT	146	153	160	167	175	182	189	197	204	212	219	227	234	242	250	257	266	273	281	289	297	305	313	321	329	338	346	354	362	370
	FILL	137	134	132	130	128	126	124	123	121	119	117	116	114	113	111	110	108	107	106	104	103	102	100	99	98	97	96	95	94	93

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