ENERGY DISSIPATERS

In hydraulic engineering numerous devices like stilling basins, baffled aprons, and vortex shaft etc., are known under the collective term ENERGY DISSIPATERS. Their purpose is to dissipate hydraulic energy (convert to heat). These are also called downstream protection works and occupies a vital place in design of spillways, weirs and barrages. The problem of designing energy dissipaters is one essentially of reducing the high velocity flow to a velocity low enough to erosion, abrasion of hydraulic structures, generation of tail water waves or scouring. There are several methods of dissipating the energy of shooting flow of water. They can be classified as below:

Hydraulic Jump type Stilling Basin

(i) Horizontal apron type
(ii) Sloping apron type

Jet Diffusion & free jet stilling basin

(i) Jet diffusion basin
(ii) Interacting jet diffusion basin
(iii) Free jet stilling basin
(iv) Hump stilling basin
(v) Impact stilling basin

Bucket type energy dissipaters

(i) Solid roller bucket type
(ii) Slotted roller bucket type
(iii) Sky jump Bucket type (trajectory or shooting or flip)

Energy dissipation process can be achieved in five separate stages some of which may be combined or may be absent

(i) On the spillway surface
(ii) In a free falling jet
(iii) At impact into a Down stream pool
(iv) In the stilling basin
(v) At he out flow into a river

Factors affecting the design of energy dissipaters

(i) Nature of foundation
(ii) Magnitude of flood & their occurrence
(iii) Velocity of flow
(iv) Orientation of flow
(v) Depth discharge and its relationship at the site of structure

Last factor is most important. A thorough knowledge of its implications on the design of energy dissipaters is a pre-requisite for the most efficient and cheapest type of structure.
For example the relationship of tail water depth and tail water depth play a crucial rule in efficient energy dissipation.

Relationship of tail water curve(TWC) to Jump height curve(JHC)

The JHC may be related to TWC in five different ways:

Jump height curve (JHC) always above the tail-water curve(TWC)

This means that the depth of flow in the river in particular section is in sufficient for all discharges for formation of jump at the toe of structure. The jump will try to sweep across the apron at a high velocity and attack the bed down stream. The energy dissipation can be achieved in any of the following ways:

(a) Lowering the floor level D/S of the spillway so as to make the tail water depth in the stilling basin equal to jump height curve for all discharges. This may lead to three cases:

(i) Horizontal floor but depressed below the river bed level
(ii) A depressed floor but rising towards the Downstream end
(iii) A depressed floor but sloping away from the toe of spillway

(b) Stilling basin with baffles or sills at river bed level
(c) Stilling basin with a low subsidiary dam downstream.
(d) Bucket type structure---- If under the conditions of low tail water depth there is a bed of solid rock which can withstand the impact of water, Ski Jump bucket energy dissipater may be adopted. Such a device will throw the high velocity flow passing over the spillway upwards so it travels some distance from the toe of the spillway before it falls back and strikes the river bed. Here the energy is dissipated by the aeration of the jet and impact of the water on the river bottom. Though some scour takes place, it is too small or too far from the dam to endanger it.

2. Jump height curve always below the tail water rating curve

with higher depth of tail water, the tendency of high velocity flow is to drive under the water and travel a long distance along the bottom and forming only a very imperfect jump. The energy dissipater can be done in the following ways:

(i) Providing a sloping apron
(ii) Roller bucket type energy dissipater

3. Jump height curve above tail water rating curve at low discharges and below it at higher discharges.

A horizontal apron in river level in this case provides an insufficient depth at low discharges and extra depth for high discharges to form a suitable Hydraulic Jump. The solution therefore, lies in creating artificially enough water depth to make the jump form on apron at low discharges.

The following may be adopted:
(a) Stilling basin with a low secondary dam
(b) Stilling basin with baffle piers or some form of dentated sill

4. Jump height curve below the tail water curve at low discharges and above it at higher discharges

The main condition to be met in this case is the provision of sufficient depth of tail water for formation of jump in high flows.
Construction of a secondary dam or a sloping will serve the purpose.

5. Jump height curve corresponds to post jump depth for all discharges

Provide a horizontal concrete apron and stilling basin

USBR TYPE STILLING BASINS

(1) <u>stilling basins for Froude's number between 1.7 and 2.5.</u>

For this case

only a horizontal apron needs to be provided. As the flow in this case does not have much turbulence usually no accessories are required to be provided. However, the apron should be sufficiently long to contain the entire jump over it.

Length of apron = Length of jump = 5 Y_2, where Y_2 is the sequent depth.

(2) <u>Stilling basins for Froudes number between 2.5 and 4.5</u>

For this range of Froudes number Type I stilling basin has been found to be effective for dissipating the energy of flow. The basin is provided with chute blocks. The length L of the stilling basin may be obtained for different values of F_1 from the following table:

F_1	2	3	4	5
L/Y_2	4.3	5.3	5.8	6

In this case due to oscillating jump being developed, wave action is produced which cnnot be entirely dampened. However in order to suppress the wave action the floor of the basin should be so set that the tail water depth in the basin is 10 % greater than the sequent depth Y_2. this will also check the tendency of the jump to sweep out of the basin.

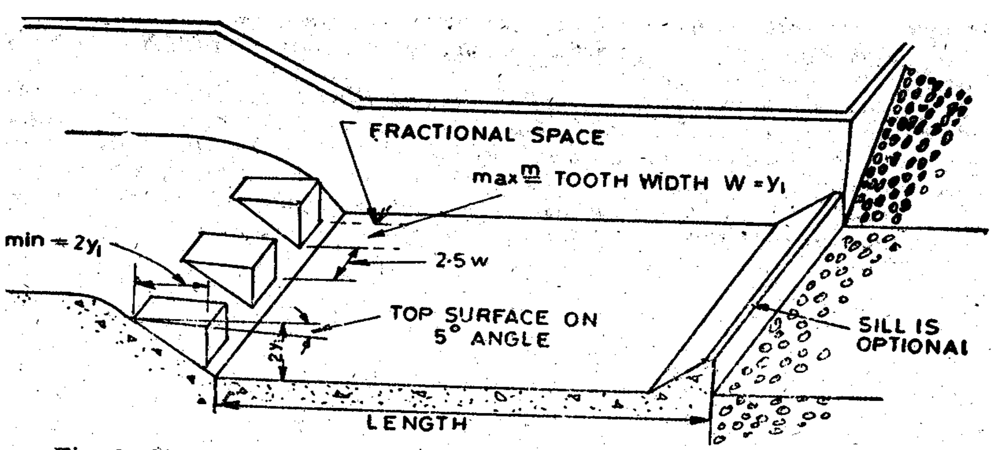


Fig. 21·33. U.S.S.R. Stilling Basin IV (F_1 lies between 2·5 and 4·5).

Table 21·15

F_1	Length of the basin
4	$3{\cdot}6\ y_2$
6	$4\ y_2$
8	$4{\cdot}2\ y_2$
10 or more	$4{\cdot}3\ y_2$

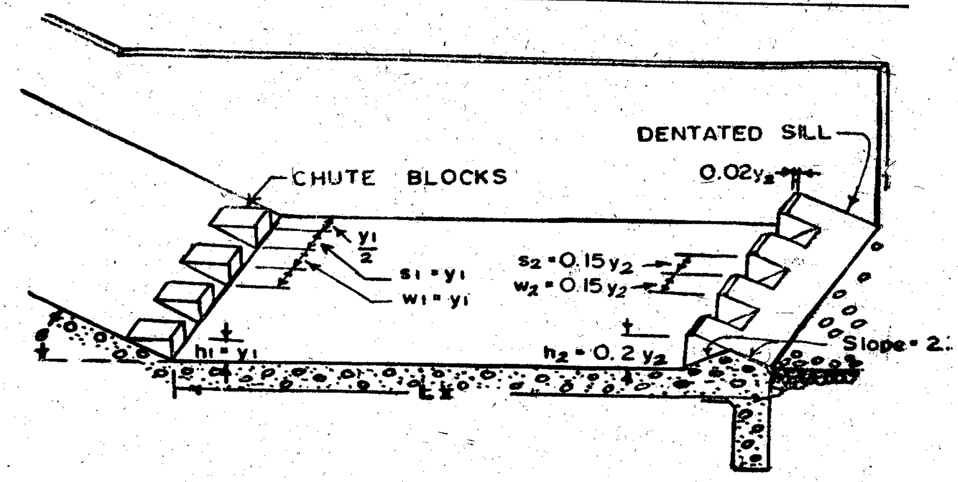
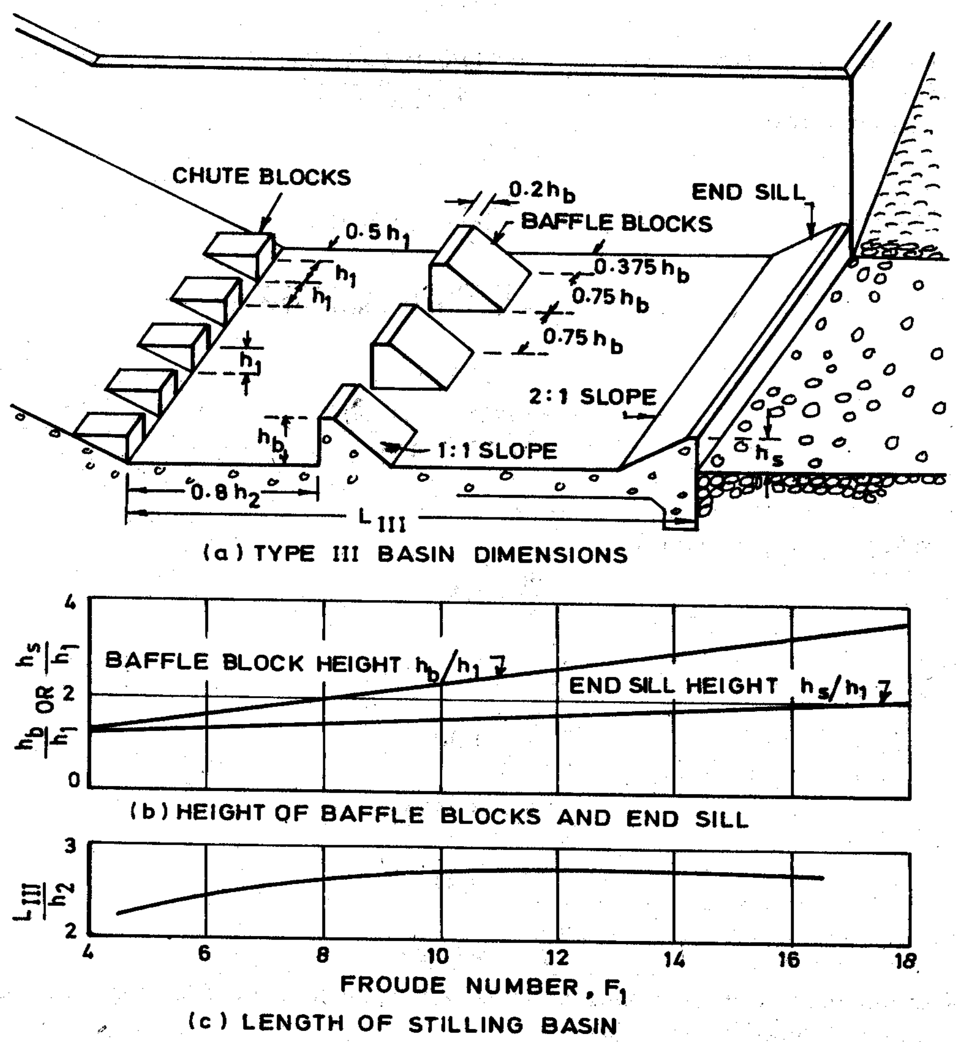


Fig. 21·32. U.S.B.R. Stilling basin II ($F_1 > 4{\cdot}5$).



(3) Stilling basins for Froudes number higher than 4.5

For this case depending upon the velocity of incoming flow, two types of of stilling basin have been developed as indicated below.

(a) when the velocity of incoming flow is less than 15m/s, Type II stilling basin have been adopted. This basin utilizes CHUTE BLOCKS, BAFFLE BLOCK and an ENDSILL. The size, spacing and location of the chute and baffles blocks are shown in figure. The length L of the stilling basin and the heights h_3 and h_4 of the baffle blocks and end sill respectively may be obtained for different values of F_1 from the following table:

F_1	5	6	8	10	12	14	16
L/Y_2	2.3	2.5	2.6	2.7	2.8	2.8	2.8
h_3/y_1	1.5	1.7	2.0	2.3	2.7	3.0	3.3
h_4/Y_1	1.2	1.3	1.5	1.6	1.7	1.8	1.9

Where Y_1 and Y_3 are initial and sequent depths

By providing the baffle blocks the length of the stilling basin is considerably reduced because the dissipation of energy is accomplished by the hydraulic jump as well as by the impinging action of the incoming flow against these blocks. However, the baffle blocks will be subjected to large impact forces due to impingement of incoming flow. Moreover on the downstream face of the baffle blocks usually suction or negative pressure will be developed which will further increase the forces acting on these blocks. Hence, baffle blocks should be properly anchored at the base. Further the floor of the basin will also be subjected to additional load due to the dynamic forces created against the upstream face of the baffle blocks, which should be considered in the design of the floor of the basin.

(b) When the velocity of the incoming velocity exceeds 15 m/s, TYPE III STILLING BASIN may be adopted. In this basin only chute blocks are provided and instead of a solid end sill a dentate sill is provide. In this basin baffle blocks are not provided because

(i) Due to high velocity of incoming flows these blocks will be subjected to excessive large impact forces and

(ii) There is a possibility of cavitation along the downstream face of theses blocks and adjacent floor of the basin due to large negative pressure developed in the region.

However, due to baffle blocks being eliminated in this case the dissipation of the energy is primarily accomplished by hydraulic jump and hence the length of the basin will be greater than that indicated for the TYPE II BASIN. The length of TYPE III stilling basin may be obtained for different values of F_1 from the following table:

F_1	5	6	8	10	12	14
L/Y_2	3.85	4.0	4.2	4.3	4.3	4.3

Again in this case also in order to check the tendency of the jump to sweep out of the basin the floor of the basin is so set that the tail water depth in the basin is 5% greater than the sequent depth.

Bucket type energy dissipaters

A bucket type energy dissipaters consists of an upturned bucket provided at the toe of the spillway. The bucket type energy dissipaters may be used only for overflow type spillways. This type of energy dissipation becomes more economical than the method of stilling basins when the Froude number F_1 of the incoming flow exceeds 10, because in such cases the difference between initial and sequent depths being large a long and stilling basin would be required. Moreover the bucket type energy dissipaters may be used with any tail water condition. However, this type of energy dissipater may be used only when the river bed is composed of stiff rock. The bucket type energy dissipaters are of the following three types:

(i) Solid roller Bucket

(ii) Slotted roller Bucket

(iii) Ski jump (or flip or trajectory bucket)

The solid or slotted roller bucket may be used where the tail water depths are too large as compared to the sequent depths required for the formation of the hydraulic jump. Both these buckets remain submerged in tail water and hence these are also termed as submerged bucket type energy dissipaters. The solid and slotted roller buckets are discussed as under:

(i) Solid roller Bucket

A solid roller bucket consists of a bucket like apron with a concave circular profile of large radius and a deflector lip as shown. When the water flows over the bucket the entire sheet of water leaving the bucket is deflected upward by the bucket lip and two elliptical rollers are developed as shown in the figure. One of the roller which moves in the counter clock wise direction is developed on the surface of the bucket and is contained within the region above the bucket. This is known as bucket roller (or surface roller). The other roller moving in the clock wise direction is developed on the ground surface immediately downstream of the bucket, which is known as ground roller, the movement of the rollers, along with the intermingling of the incoming flows causes the dissipation of the energy.

The upward deflection of water by the bucket lip creates a high boil on the water surface and a violent ground roller. This ground roller continuously pulls the loose bed material backwards and deposits the same against the lip of the bucket. Some of the materials may move into the bucket, which may get trapped there and damage the surface of the bucket by abrasion. Moreover due to severe surface boil the turbulent flow persists for a considerable distance on downstream side thus resulting in the erosion of the river banks. These drawbacks of the solid roller bucket are removed in slotted roller bucket.

Radius of the Bucket: $R = 0.6\sqrt{H' * H_d}$

Where H' = fall from crest of spillway to bucket invert in meter.

And H_d =Head over crest in meters

Vente Chow's Formula $R = 0.306 * 10^k$

Where $k = (v_1 + 6.4 H_d + 4.88)/(3.6 H_d + 19.5)$

V_1 = velocity of flow at the toe of spillway in m/s

Slotted Roller Bucket

A slotted roller bucket also consists of a bucket like apron with a concave circular profile of large radius but it has a slotted (or dentated) deflector lip. In general the hydraulic action of the slotted bucket has the same characteristics as that of a solid bucket. Thus in the case of the slotted bucket also the same two rollers are developed. However in this case the water leaves the lip of the bucket at a flatter angle and only a part of it is deflected upwards. Thus surface boil is considerably reduced, and less violent ground rollers occurs which results in a smoother flow on the downstream side. Moreover in this case the bed material is neither deposited nor carried away from the bucket lip, also any debris which might get into the bucket is immediately washed out through the slots. However the performance of the slotted bucket is considerably affected by tail water depth. At low tail water depths the bucket roller will be swept out of bucket and will produce high velocity flow on the downstream side which will scour the river bed. On the other hand when the tail water depths becomes excessively large the jet water leaving the bucket will get depressed and drive to the river bed which will scour the river bed at the point of impingement. Thus the slotted roller buckets are suitable only for alimited range of tail water depths

SKI JUMP BUCKET

A ski jump bucket may be used where the tail water depth, is less than sequent depth required for the formation of hydraulic jump and the river bed is composed of stiff rock. The lip of the bucket is so shaped that the entire sheet of the water flowing over the bucket is deflected as a free jet which falls back into the river channel at a safe distance away from the spillway. Thus in this case energy is dissipated by air resistance, breaking of the jet into bubbles and the impact of the falling jet against the river bed and tail water.

BUCKET INVERT level is decided mainly from the structural point of view. If the power house is situated below the ski jump bucket, then the invert should be fixed higher than the roof top of power house. In some cases bucket is lower than the tail water the bucket invert then is so decided so as to provide a concrete cover of 1.5m to 3.0m over the bed of rock. The pure ski jump or flip as it is often called is provided such that bucket lip is always higher than the maximum tail water depth.

Bucket Radius has the same formula as the solid roller bucket.

Entrance and exit slope:

For the entrance slope, the steepest spillway slope that should be used is 4 vertical to 1 horizontal. The exit angle ϕ is an important factor in determining the length of the trajectory. Theoretically if friction, air retardation etc., are neglected, the formula to be used to evaluate the horizontal component of the jet trajectory

$$X = (V_o^2/g) \sin 2\phi$$

Jet trajectory height is given by $Y = h \sin^2\phi = (V_o^2/2g) \sin^2\phi$

A judicious selection of exit angle is necessary, an exit angle of 30^o to 35^o is a good choice. When the maximum tail water is lower than the bucket lip shape of the lip is kept flatter for ease of construction. High sub atmospheric pressure at down stream lip has to be avoided by aeration or provide a curved or sloping lip.

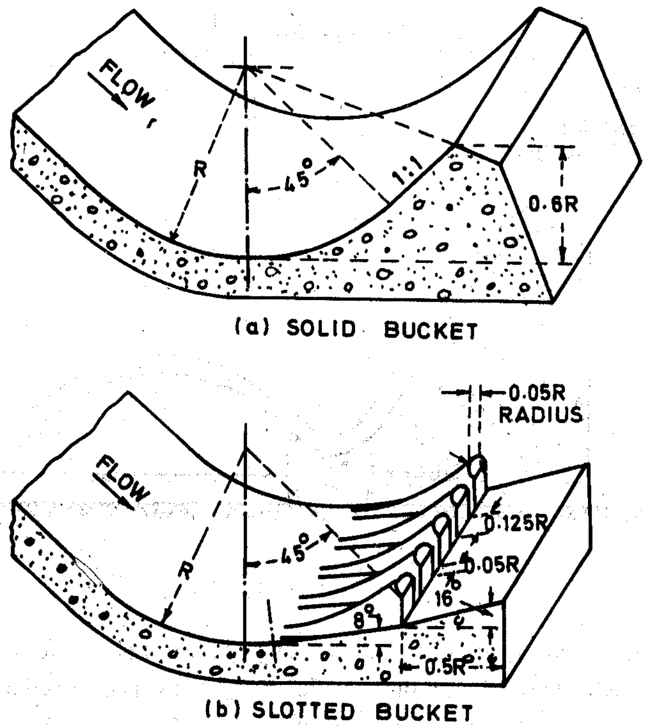


Fig. 17.21 Roller Buckets

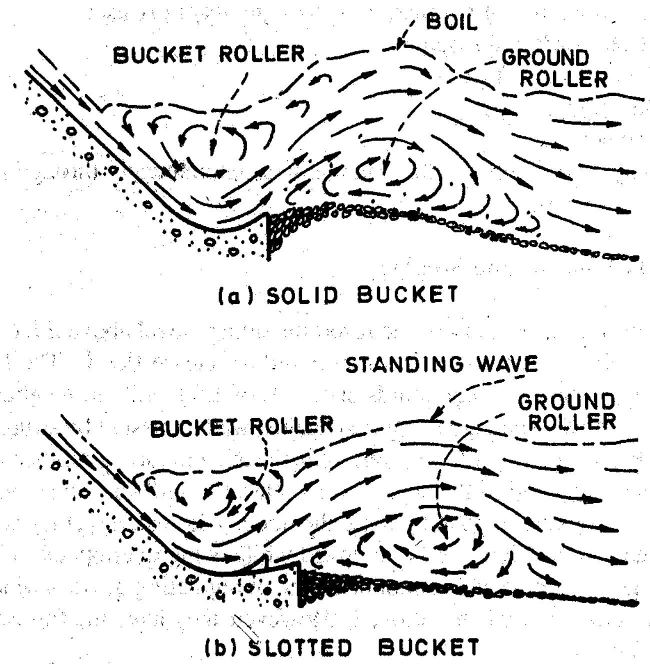
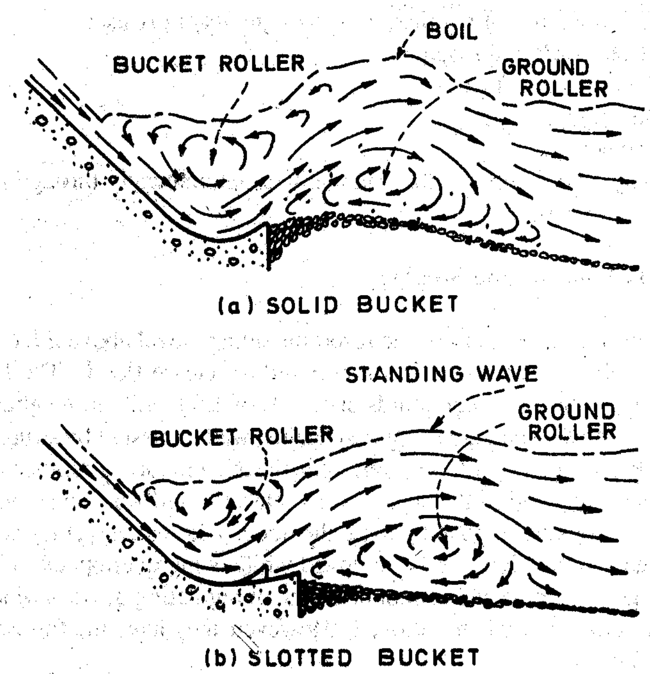


Fig. 17.22 Roller Formation in Roller Buckets



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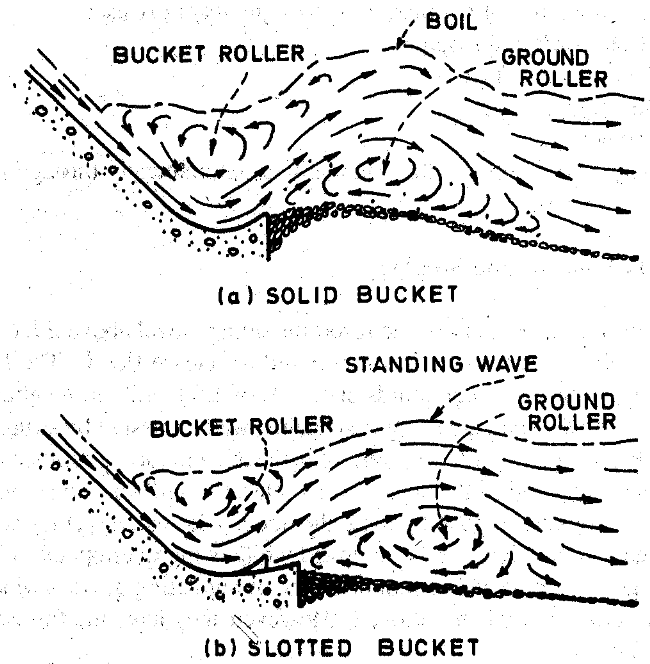

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