IS 11388 (2012): Recommendations for Design of Trash Racks for Intakes [WRD 14: Water Conductor Systems]

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Indian Standard

RECOMMENDATIONS FOR DESIGN OF TRASH RACKS FOR INTAKES

(Second Revision)

ICS 93.16

BUREAU OF INDIAN STANDARDS
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Water Conductor Systems Sectional Committee, WRD 14

FOREWORD

This Indian Standard (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Water Conductor Systems Sectional Committee had been approved by the Water Resources Division Council.

Trash racks are provided at the entrance of intakes. The design of trash racks should be such as to result in minimum hydraulic losses and prevent/minimize ice, floating trash, etc, from entering the tunnel or channel.

This standard was first published in 1985 and subsequently revised in 1995. This revision has been formulated in view of the experience gained during the course of these years in the use of the standard. The following changes have been incorporated in this revision:

a) Kirschmer formula has been added for calculation of losses at trash racks;
b) Value of factor K for circular bar been changed to 1.79 instead of 1.29;
c) Formula for calculating forced frequency has been added; and
d) Allowable clogging restricted to 33 percent from 50 percent and hydraulic load due to allowable clogging to be considered in the design.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

RECOMMENDATIONS FOR DESIGN OF TRASH RACKS FOR INTAKES

(Second Revision)

1 SCOPE

This standard lays down recommendations for design of trash racks provided at the entrance of intakes to protect turbines, pumps, valves, etc, from objectionably large debris.

2 REFERENCES

The following standards contain provisions, which through reference in this text, continue provisions of this standard. At the time of publication the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
800 : 2007	Code of practice for general construction in steel (*third revision*)
2062 : 2006	Hot rolled low, medium and high tensile structural steel (*sixth revision*)

3 CLASSIFICATIONS OF TRASH RACKS

The trash racks may be classified into the following types in accordance with their constructional features and the methods of installation:

a) *Type* 1 — Removable section racks which are installed by lowering the sections between side guides or grooves provided in the trash rack structure so that the sections may be readily removed by lifting them from guides. These are generally side bearing type.

b) *Type* 2 — Removable section racks in which the individual sections are not installed between guides in the trash rack structure, but are placed adjacent to each other laterally and in an inclined plane to obtain the desired area of flow. Since rack sections may easily be displaced, these have to be secured in place with bolts located above the water line.

c) *Type* 3 — Trash rack sections which are bolted in place below water line.

4 SELECTION OF TYPE

4.1 The selection of type of rack for an installation depends upon the following considerations:

a) Accessibility for maintenance or replacement;
b) Size and quantity of trash expected; and
c) Mechanism available for raking.

4.2 The following criteria should be followed for selecting the type of trash racks for any installation:

a) Racks of Type 1 should be used for all major trash rack installations where a portion of rack is deeply submerged;
b) Racks of Type 2 should be used for canal head works and for pumping plants where single rack section extends from water surface to the bottom of rack; and
c) Racks of Type 3 should be used where power driven cleaning rakes are required for cleaning them. This type of rack is particularly adopted for completely submerged intakes.

5 INCLINATIONS OF RACKS

Racks should be installed in slanting position except for guided racks where these can be kept in vertical position as well. For manual raking of the racks, the slope should be 1 vertical to 1/3 or 1/2 horizontal. For racks which are to be cleaned by mechanical means, the slope should be 10° to 15° with the vertical unless otherwise specified by the trash rack cleaning machine manufacturer's manual.

6 VELOCITY THROUGH RACKS

6.1 For low pressure intakes with small units (and consequently closely set rack bars) and where manual cleaning of racks is provided the velocity should be limited to 0.75 m/s. With large units (and wider spacing of rack bars) and where mechanical cleaning of racks is provided a velocity up to 1.5 m/s should be permitted.

6.2 For high pressure intakes the overall economy will determine the velocity to be used in racks. Velocity up to 3 m/s on the gross area of racks may be permitted where serious clogging of trash racks is not expected for high-pressure intakes.

7 LOSSES AT TRASH RACKS

7.1 The loss of head should be calculated from the following formula:

$$\text{Head loss} = \frac{KV^2}{2g}$$

where

K = trash rack loss coefficient ($1.45 - 0.45\,R - R^2$);

R = $\dfrac{\text{net area through the rack bars}}{\text{gross area of the racks and supports}}$

V = velocity of flow through trash rack, computed on gross area, and

g = acceleration due to gravity.

Alternatively, the following Kirschmer formula can also be used :

$$h_r = K_s\left[\frac{t}{b}\right]^{4/3} \times \frac{v^2}{2g} \times \sin\alpha$$

where

h_r = loss of head through racks;

t = thickness of bars;

b = clear spacing between bars;

v = velocity of flow through trash rack, computed gross area;

$\propto$ = angle of bar inclination to horizontal;

K_s = factor depending on bar shape in accordance with Fig. 1; and

g = acceleration due to gravity.

NOTE — h_r computed from the above formula is multiplied by a factor 1.75 to 2.00 to take care of bracings and frame.

Allowance should also be made for partial clogging of racks with trash 25 to 50 percent of area of racks may get obstructed in practical operation, where the amount of debris is considerable.

8 STRUCTURAL DESIGN OF TRASH RACKS

8.1 General Arrangement

The structural arrangement of racks generally consist of equally spaced trash rack vertical bars supported on horizontal members connected to end vertical members, which sit in the grooves of piers (*see* Fig. 2). The size of each trash rack unit should be proportioned from consideration of hoisting/lifting capacity.

8.2 Materials

The trash rack should be constructed from structural steel conforming to IS 800 and IS 2062.

8.3 Design Head

The trash rack should be designed for the following loads:

a) Racks protecting power intakes should generally be designed to withstand 6.0 m differential hydraulic head;
b) Steel supporting members other than trash bars should be designed for a differential hydraulic head of 7.0 m; and
c) Hydraulic pressure due to allowable clogging.

8.4 Spacing of Trash Bars

The clear spacing usually varies from 40 mm to 100 mm. In case of small turbines, it is necessary to use close spacing of trash bars. For large units, much wider spacing is permitted.

8.4.1 For Francis type turbines, the spacing of trash

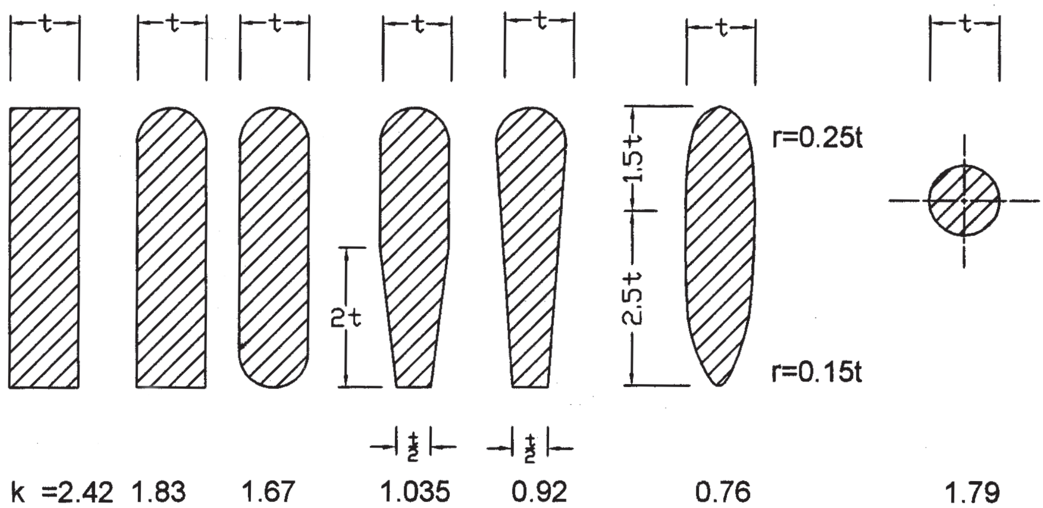

FIG. 1 VALUES OF FACTOR 'K' FOR VARIOUS BAR SHAPES

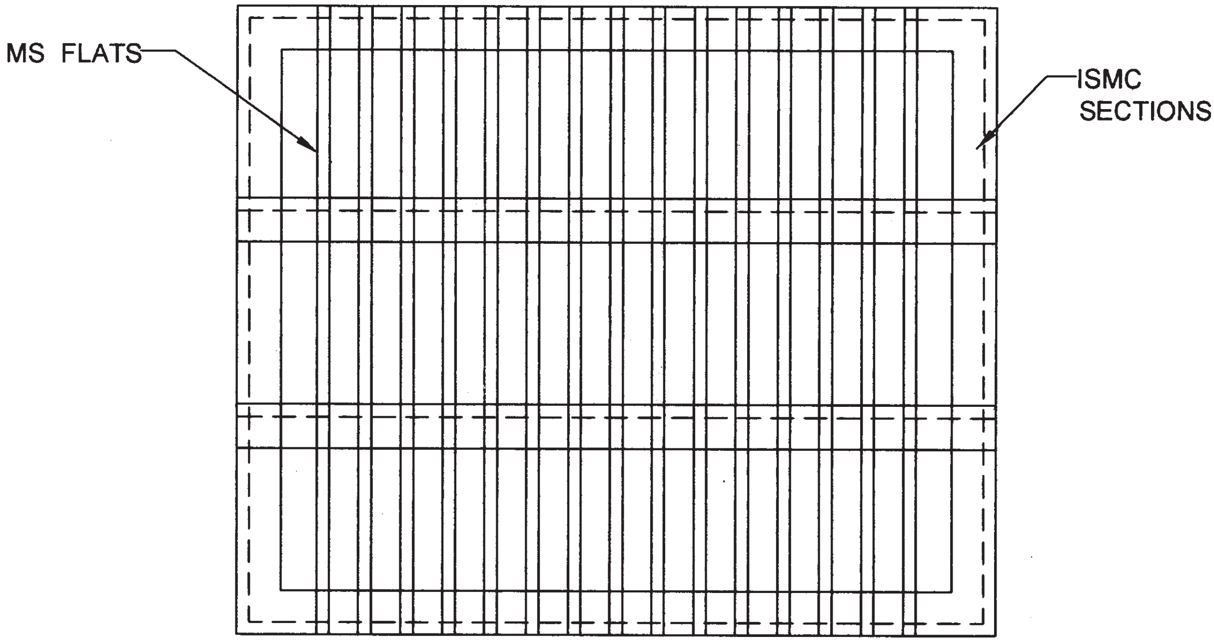

FIG. 2 METALLIC TRASH RACK

bars should be determined from Fig. 3 using the value of D_3 corresponding to the diameter of the runner. Trash rack bars should be so spaced so that the net opening between them should not be greater than the minimum opening between turbine runner buckets.

If the minimum opening dimension is not known, it may be approximated from the following equation and the value of '*F*' obtained from the curve (*see* Fig. 3):

$$\text{Net opening between bars (m)} = \frac{F \times D_3}{\text{Number of buckets in runner}}$$

NOTE — For preliminary design assume 19 buckets, if actual number is unknown.

8.4.2 For propeller type of turbines, the spacing of trash rack bars should be determined as given below:

a) 75 to 150 mm — for diameter of runner varying between 2.5 m and 5.0 m; and
b) 150 to 250 mm — for diameter of runner varying between 5.0 and 7.5 m, that is, about 1/30 of runner diameter in case of propeller or Kaplan turbine.

8.4.3 For impulse turbines, the spacing between trash rack bars should not be larger than 1/5 of the jet diameter at maximum needle opening but in case of very small impulse turbine, mesh screen should be permitted.

8.5 Design of Trash Bars

The depth of trash bar should not be more than 12 times its thickness and not less than 50 mm. For racks which may require mechanical raking, the distance from the face of the rack to the spacers or other horizontal members should be at least 40 mm. The laterally unsupported length of trash rack bars should not exceed 70 times its thickness. Racks should be provided with bearing pads not less than 10 mm thick, which come in contact with the concrete grooves thus protecting the protective coating of racks from abrasion.

Trash rack bars should be assumed to fail when the stress in the bar reaches the following value:

$$\text{Failure stress} = Y_{\text{ps}}\left(1.23 - 0.015\,3\frac{L}{t}\right)$$

where

Y_{ps} = yield point stress;
L = laterally unsupported length of bar; and
t = thickness of bar.

Similarly safe working stress for trash rack bars used to support flash boards should not exceed the following value :

$$\text{Safe stress} = 0.66\ Y_{\text{ps}}\left(1.23 - 0.015\,3\frac{L}{t}\right)$$

8.5.1 *Thickness of Trash Bars*

The minimum thickness of trash bars recommended for Type 2 and Type 3 trash racks is 8 mm. For deep submerged racks, the minimum thickness should be kept as 12 mm. The ratio of width to thickness of bar can be taken between 5 and 12.

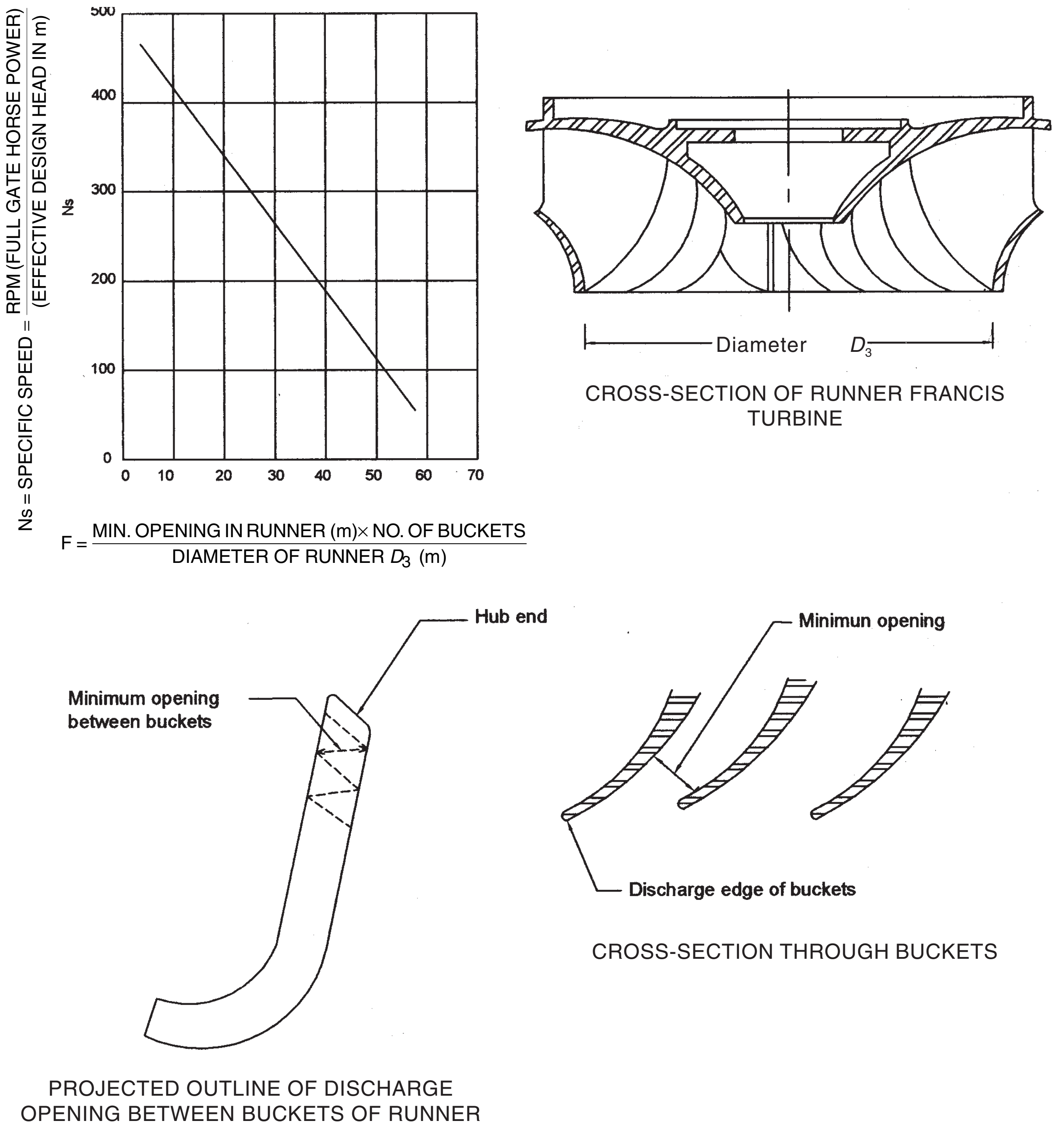

FIG. 3 TRASH RACK BARS SPACING FOR FRANCIS TURBINE

8.6 Design of Horizontal Members

Members used as horizontal beams in trash rack sections should not require stress reduction to compensate for lack of lateral support. These members should be assumed to fail at yield point stress but calculations should include stress due to dead weight of the beam members and trash rack bars. To ensure rigidity during handling, the lateral deflection of the beam members due to load should not exceed 1/325 of the span.

8.7 Check for Stability Against Vibrations

Trash racks should be checked for resonance while operating under turbine and pumping modes and the design and disposition of the members should be so made that resonance does not take place. The main consideration should be for limiting the forcing frequency less than natural frequency, as the point at which vibration starts is $f_r/f_n \leq 0.65$ where f_r = forcing frequency, and f_n = natural frequency. The ratio of forcing frequency to natural frequency should not be more than 0.6 for normal design, However, a high ratio be permitted for a short period but the maximum value should not exceed 0.65.

The forced frequency should be calculated as :

$$F_i = \frac{S_t V_{eff}}{t}$$

where

F_i = forced frequency,

S_t = strouhal number (as shown in Fig. 4),

V_{eff} = effective velocity referred to net cross-section area, and

t = thickness of bar.

The natural frequency should be calculated as:

$$F_n = \frac{pK_f^2}{2} \{(EIg)/ [V (\gamma_s + \gamma b_e / t) /3]\}^{½}$$

where

F_n = natural frequency; and

K_f = constant characterizing grade of fixity and degree of oscillation of bars.

For free ends K_f = 1, 2, 3 ……, etc

For fixed ends K_f = 1.5, 2.5, 3.5 ……….etc

E = young's modulus of elasticity;

I = moment of inertia of the bar profile related to its axis parallel to flow direction;

g = acceleration due to gravity;

V = volume of unrestrained part of the bar;

γ_s = specific weight of bar;

γ = specific weight of water;

b_e = effective bar clearance that is 0.7 times width of bar or rack clearance whichever is less;

t = thickness of bar.

9 STRUCTURAL DETAILS

9.1 Structural connections in the trash rack should be designed and provided for the failure load of the structural members. All flats should be welded to the intermediate horizontal members and the top and bottom horizontal members for better resistance to vibrations and to avoid stress concentration at the external edge of the groove. The vertical member of the trash rack should be so arranged as to apply the load near the inner part of the rack guide.

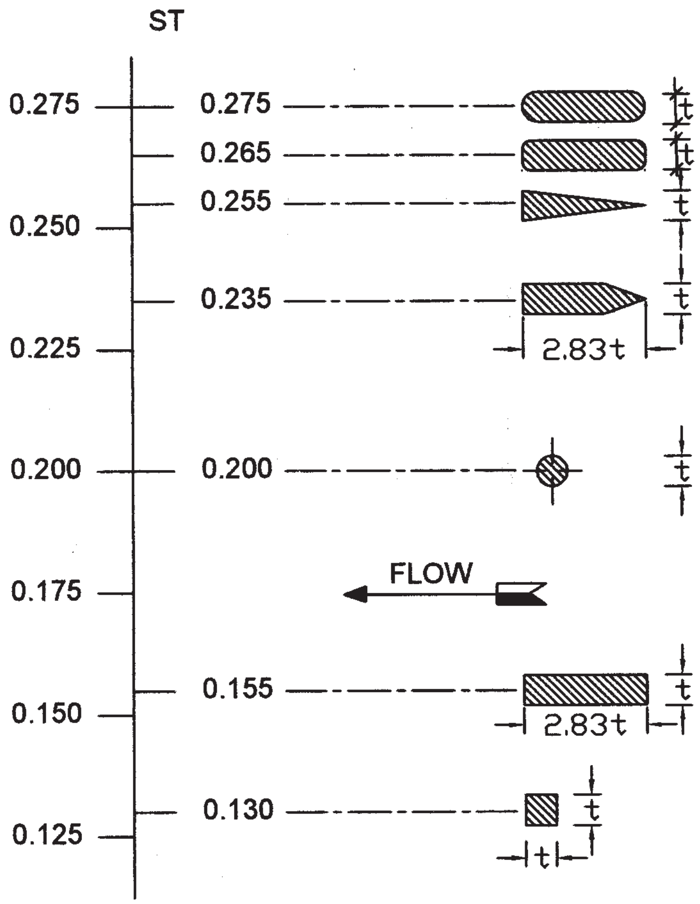

FIG. 4 STROUHAL NUMBERS PERTAINING TO VARIOUS SHAPINGS OF THE CROSS-SECTION OF THE RACK BARS

9.2 Type 1 racks, where used in tiers, should be equipped with dowels of sufficient size to ensure proper alignment of the racks in the guides.

9.3 The guides of the trash racks should be so proportioned that the side members (if the same are not rigid enough to carry dead load of upper rack sections) get lateral support from guides after deflection to take up the clearance in the slots.

9.4 In case of Type 1 trash racks, the height of unit should be equal to spacing of horizontal concrete arch ribs of intake structure or convenient fraction of the same.

9.5 For proper seating of one trash rack unit above the other, pilot shoes and pilot pins should be provided.

10 CONSTRUCTION AND MAINTENANCE OF TRASH RACKS

10.1 Construction

10.1.1 The trash bars should preferably be fabricated from flats with rounded edges.

10.1.2 Lateral support to the bars should be provided intermediately between end supports. The spacers, if used, should be arranged as far back as possible from the upstream face of the bars so as not to interfere with the movement of rake.

10.1.3 To simplify site erection, the trash rack panels should be identical.

10.1.4 The bars of any panel should be directly in line with the corresponding bar above or below, so that cleaning rake operates satisfactorily while passing up and down the screen.

10.1.5 If no crane is provided for handling the racks, they should be made in sections sufficiently light for manual removal and replacement.

10.2 Design Requirements for Maintenance

10.2.1 Suitable arrangement should be made for cleaning the racks mechanically or manually at regular intervals. The frequency of cleaning of the racks would depend upon the rate of accumulation of trash. Not more than 33 percent of the trash rack area should be allowed to clog the racks at any time.

10.2.2 In case of intakes of Type 1 located in a reservoir, a platform should be provided at a suitable level above the trash rack structure, so that the same can be used as maintenance platform. The level of the platform should be fixed such that the water level in the pond or reservoir should go below the platform level at least once in a year. Arbitrarily this level can be fixed at a height of at least 5 m above the minimum draw down level (MDDL).

10.2.3 Hooks should be provided in each rack to enable lifting of the rack in Type 1, wherever necessary, for cleaning. Chains may be attached to these hooks and the end of the chains may be tied to the top platform to facilitate lifting of the racks.

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Amendments Issued Since Publication

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