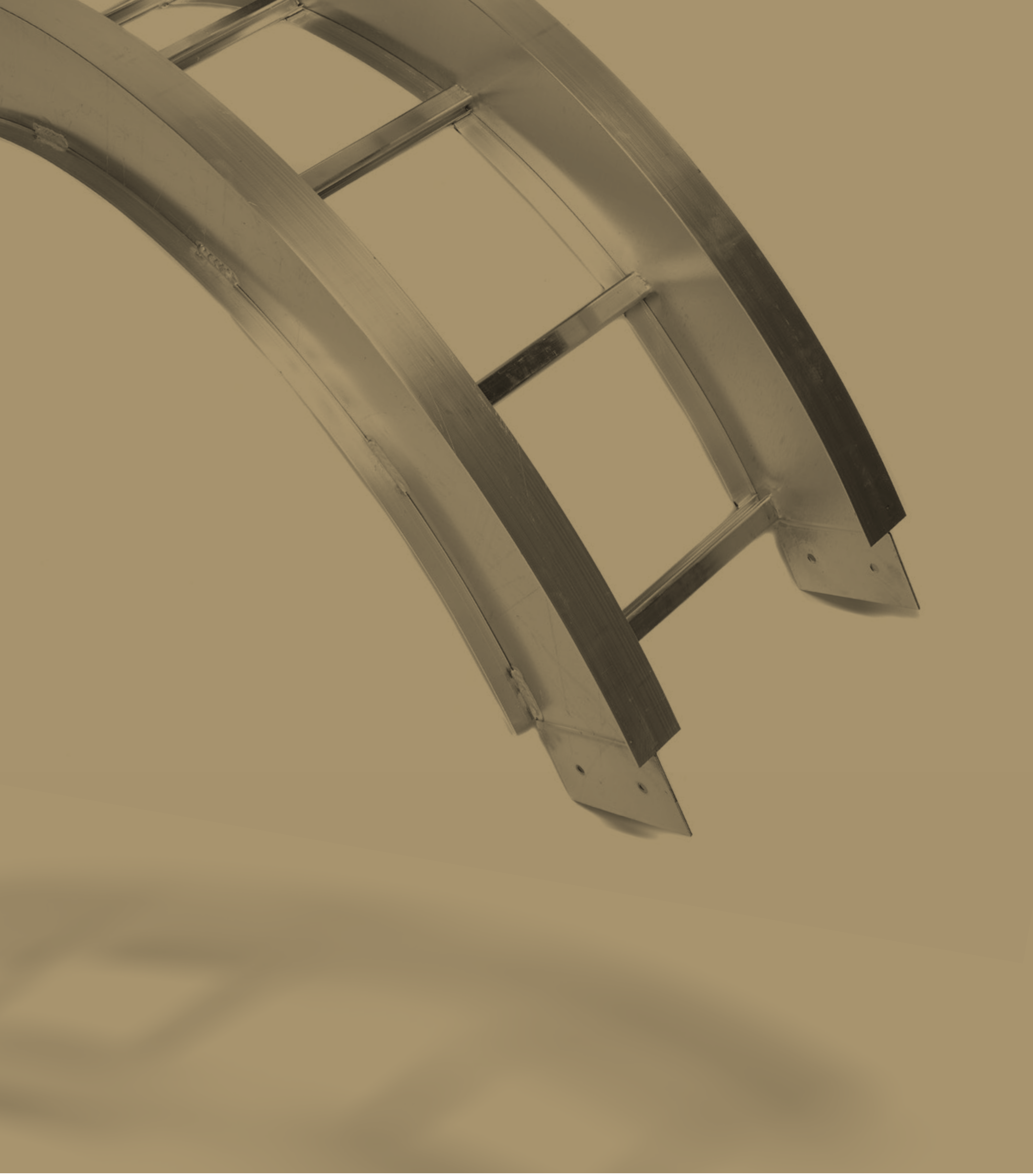
TECHNICAL AND SIZING DATA



UNITRAY
SYSTEMS INC

UNITRAY IS 100% CANADIAN OWNED AND OPERATED. WE WORK TO ACHIEVE THE QUALITY AND RELIABILITY THAT OUR INDUSTRY DEMANDS

We have more than a decade's worth of experience making and designing quality cable tray and cable management systems. Our knowledgeable production team works closely with each customer to provide quality solutions based on your schedule and budget.

We want each and every experience with our company to be a good one. Through ongoing quality assurance analysis and evaluation of our manufacturing techniques, we strive to exceed the expectations of our customers. We act with honesty, integrity and effectiveness to achieve the quality, durability, safety and reliability that our industry demands.

UNITRAY
SYSTEMS INC

C US

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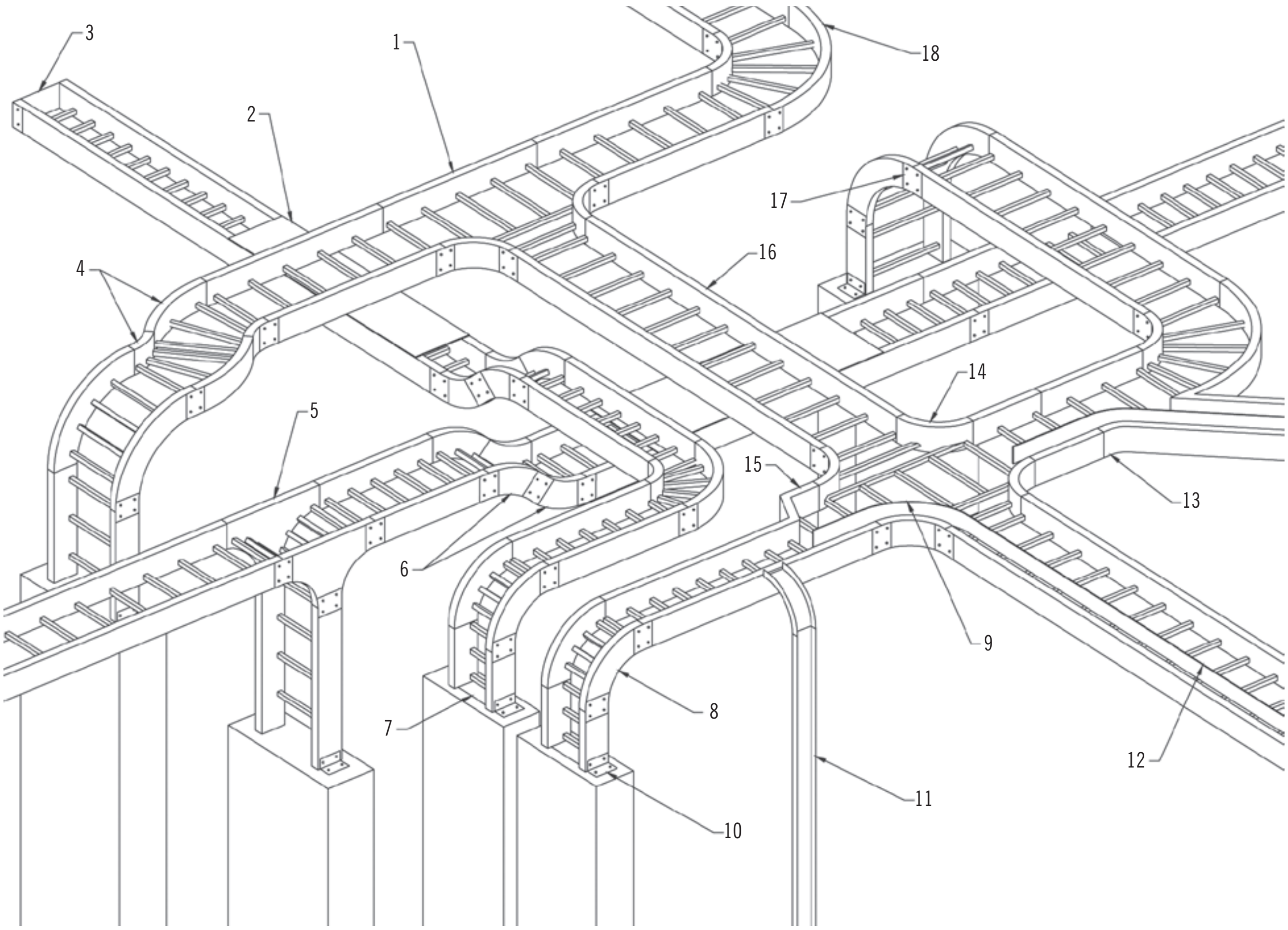


LEGEND

1. Horizontal Tee, Ladder Type (HT)
2. Flanged Solid Cover (S)
3. Blind End (BE) Connector
4. Horizontal Elbow, 30°, 45° or 60° (3H, 4H, 6H)
5. Vertical Tee, Solid Bottom (VT)
6. Vertical Elbow, Outside & Inside 30°, 45°, or 60° (3O, 3I, 4O, 4I, 6O, 6I)
7. Box Connector (BT)
8. Vertical Elbow, Outside 90° (9O)
9. Barrier Strip Flexible Horizontal Fitting (FB)
10. Angle Connector (AC)
11. Straight Section Communication Channel (SL)
12. Barrier Strip Straight Section (SB)
13. Horizontal Wye/Right hand shown (RY)
14. Horizontal Cross, Ladder Type (HX)
15. Reducing Connector (RC)
16. Straight Ladder (SL) Section
17. Universal Connector (UC)
18. Horizontal Elbow, 90°, Ladder Type (9H)

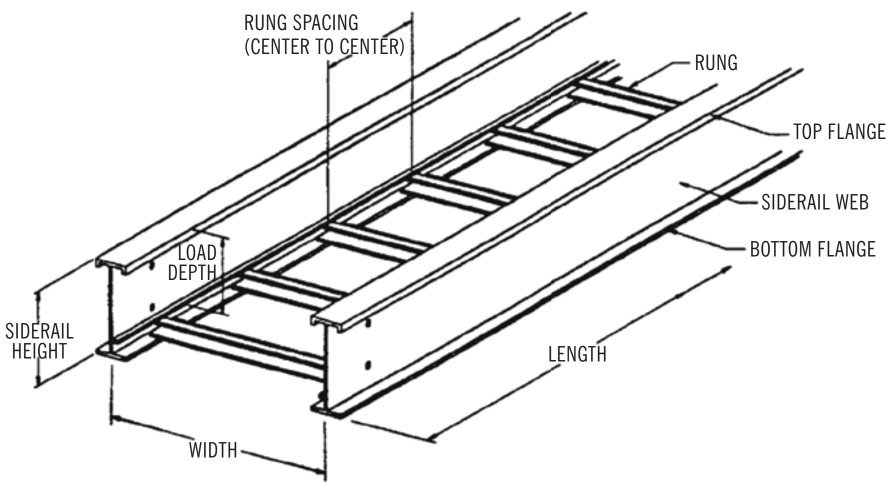
Note: All of the above with the exception of items #7 and #10 come complete with required connectors and hardware.

Unitray Systems Inc. is an Edmonton based company dedicated to excellence in the manufacturing of electrical ladder tray. Our product is both CSA and UL certified, and utilizes the latest innovations in manufacturing techniques. Unitray is proud to be 100% Canadian owned and the following catalogue will illustrate the technical competence that Unitray applies to its product; as well as to serve as a handbook in sizing ladder tray to current CSA, Canadian Electrical Code (CEC) and NEC.

TECHNICAL DATA

UNITRAY LADDER TRAY is a structure consisting of two longitudinal side members connected by individual transverse members (rungs). Rungs are welded to the side members by either cold metal transfer (CMT/GMAW) or gas tungsten arc welding (TIG/GTAW).

Both processes have their inherent advantages and are applied to the appropriate product. CMT offers advantages such as low distortion and higher precision. Benefits include higher quality welded joints, freedom from splatter, and the ability to weld light-gauge material as thin as 0.3 mm. TIG offers greater control over the weld equating to stronger, higher quality, smut and splatter free welds. This process is comparably more difficult to master and furthermore is significantly slower.



SIDERAILS:
Are based on an I-Beam (wide flange) design versus a channel shape. Over the years the I-Beam section has proven to be the most economical shape for carrying beam type loads. (15% to 20% more strength than C shape).

RUNG SPACING:
The distance measured from center of rung to center of adjacent rung. Standard rung spacing is ventilated (maximum opening of 52 mm), 150 mm, 225 mm, and 300 mm. The determination of spacing is based primarily by size and type of cable being supported.

UNITRAY LADDER TRAY TERMS

LENGTH:
The length of standard straight sections is 3 m or 6 m. 9.1 m and 12.2 m long span tray are now also available. Non-standard lengths are also available upon request.

WIDTH:
Is the perpendicular distance measured from inside of side member (rail) web to opposite side member web. Standard widths are 150 mm, 203 mm, 300 mm, 450 mm, 600 mm, 750 mm and 900 mm.

OVERALL TRAY WIDTH:
Is one of the above nominal widths plus the width of the side member flanges.

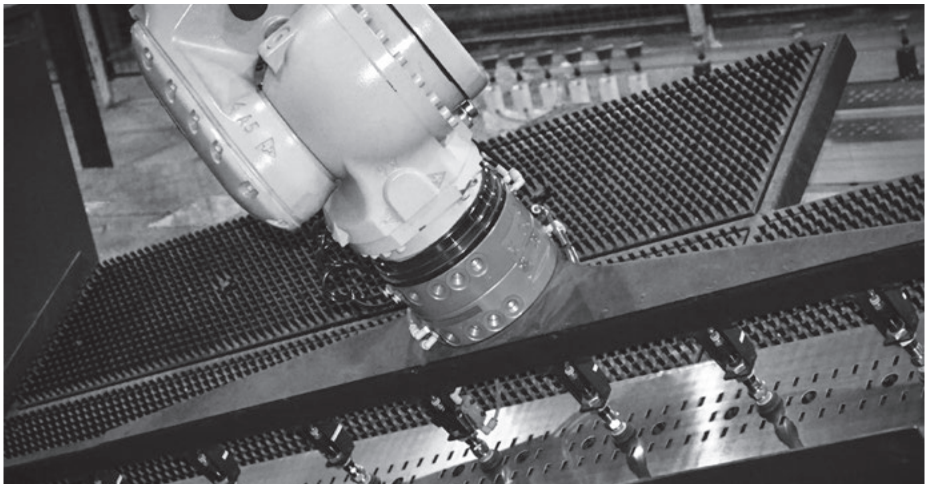
LOADING DEPTH:
This is measured from the top surface of the rung to the top of the siderail. This is not the same as siderail height. Unitray manufacturers five loading depths: aluminum 66 mm, 90 mm, 128 mm, 137, and 175 mm in accordance with CSA standard C22.2 No. 126 M-91 and UL.

FITTINGS:
Are used for changing directions on both vertical and horizontal planes. Unitray manufacturers elbows, tees, and crosses in all widths and heights. These products are available in 4 radii (305 mm, 610 mm, 915 mm and 1220 mm) and 4 degrees (30, 45, 60, and 90). With the exception of ventilated fittings and solid fittings, a normal spacing of 225 mm through the middle of the fitting is maintained.

MATERIAL TYPE:
Aluminum tray is extruded heat treated 6063-T5 (minimum tensile strength 30,000 psi). Accessories are produced from aluminum alloy 5052-H34.

UNITRAY COMPETITIVE ADVANTAGES

1. 100% Canadian Owned, CSA and UL certified.
2. Complete technical support and service for Unitray product lines.
3. Custom sizing and non-standard tray lengths are available.
4. Interchangeable with other ladder tray systems.
5. Superior siderail design allows for a light yet strong CSA load rated tray.
6. Full line of covers and accessories.
7. Rung design allows for the use of the complete line of Unistrut one piece clamps.
8. Flat surface with rounded edges allows for ease of cable pulling.
9. Unitray product has approximately 5.2' of weldment per 12" rung spacing tray, making the tray substantially stronger than our competitor’s ladder tray.
10. All Unitray fittings have zero tangents for the use of more straight runs resulting in more effective cooling.
11. All vertical fittings have one piece siderail construction with the connecting plates built in.
12. Using Unitray will result in a superior product and installation cost savings.



TRAY FLOOR / BOTTOM:
Prime consideration is type of cable being placed in tray.

1. Small diameter flexible cables i.e. control cables (require continuous bearing support) – use ventilated or solid tray.
2. Large diameter more rigid cable i.e. telephone/control cables – use ladder tray. Rung spacing 150 mm (6"), 225 mm (9"), and 300 mm (12").

TRAY CAPACITY:
Given in kilograms per lineal meter. An average load is 75 kg/m (165 lbs/ft).

TRAY WIDTH:
150 mm (6"), 203 mm (8"), 300 mm (12"), 450 mm (18"), 600 mm (24"), 750 mm (30"), 900 mm (36"), 1067 mm (42").

TRAY HEIGHT:
Not to be confused with cable loading depth.
Aluminum – 90 mm (3.5"), 114 mm (4.5"), 152 mm (6") 160 mm (6.3"), 203 mm (8").

TRAY MATERIAL:
Aluminum.

FITTING DEGREES:
30, 45, 60 and 90 degrees.

FITTING RADIUS:
305 mm (12"), 610 mm (24"), 915 mm (36") and 1220 mm (48").

TRAY SUPPORT:
Tray normally supported every 2 m, 2.5 m, 3.0 m, 4.0 m, 5.0 m, or 6.0 m.

TRAY COVERS:
Required ___ Yes ___ No

The above information will enable UNITRAY to provide your company's ladder tray requirements with precise features, competitive pricing and prompt delivery.

INTRODUCTION

This section will attempt to cover the key elements in designing a ladder tray system by outlining the main factors which a designer must address.

Once the designer has ascertained what cables are being used and their construction, he must determine the size of the ladder tray cavity. Please reference the following section on Technical Sizing Data for calculating the cable space/fill requirements.

The main selection criteria which must be covered in designing and installing a proper ladder tray system are:

- **A.** Width and height of the ladder tray
- **B.** Type of tray bottom
- **C.** Fittings
- **D.** CSA load class
- **E.** Span
- **F.** Deflection
- **G.** Materials
- **H.** Bonding
- **I.** Support Structure

A. WIDTH AND HEIGHT OF THE LADDER TRAY

Ladder tray comes in nominal widths of: 150 (6"), 203 (8"), 300 (12"), 600 (24"), 450 (18"), 750 (30") and 900 (36") mm. Most aluminum tray classes are available in 90 (3.5"), 114 (4.5"), 152 (6") mm, 160 mm (6.3") and 203 mm (8") height. Both width and the height of tray are functions of the number, size, spacing and weight of the cables in the tray. Load rating is independent of width.

Even though a 900 mm wide tray has six (6) times the volume of a 150 mm wide tray, it cannot carry any more cable weight. When piling cable in tray, the required air separation between cables can be maintained by spacing devices (eg. maple blocks).

B. TYPE OF TRAY BOTTOM

The construction and outside diameter of the smallest cable will usually determine either the rung spacing or the type of construction for the bottom of the tray. There are three (3) types of bottoms for ladder tray.

i. **LADDER** – is the most common and most economical type of tray. It is either:
   a) pre-fabricated metal structure made up of two (2) longitudinal siderails connected by individual transverse members (rungs) with openings in the longitudinal direction exceeding 52 mm (2").
   b) a open sided structure which is hung from a centre beam rather than from the sides. This type of tray bottom is used primarily for conductors enclosed in a continuous metal sheath or of the inter-locked armour types and provides maximum ventilation for cabling.

ii. **VENTILATED** – is a tray providing ventilation with a high level of protection. It is a pre-fabricated structure having longitudinal side members that are either separate or integral with a ventilated bottom. No openings can exceed 51 mm (2") in the longitudinal direction.

   This type of tray is used to support:
   a) conductors enclosed in a continuous metal sheath or of the interlocked armour types, and
   b) conductors having flame tested non-metallic coverings or sheath and moisture resistant insulation.

   As is the case with ladder tray the cable ampacity will be dependent on the spacing factor in accordance with the Canadian Electrical Code (CEC) Rule 12-2210 (1)(2). Ventilated bottoms are the best choice for smaller cables in preventing cable sagging.

iii. **NON-VENTILATED** (Solid) – is a pre-fabricated metal structure having a solid bottom that offers maximum cable protection. The cable ampacity installed in solid tray will be similar to cable installed without spacing in accordance with CEC Rule 12-1210 (3). Solid tray will carry the same type of conductors as ventilated trays. Solid bottoms completely eliminate cable sagging and offer the most protection.

Ladder tray which is available in one of three nominal rung spacings 150 mm (6"), 225 mm (9") and 300 mm (12") is most commonly used due to cost. The selection of the required rung spacing should be based on the greatest rung spacing that provides an adequate cable bearing surface area. To prevent creep in the jacket material of heavier cables, a greater surface area of the rung may be required. This concern may be addressed by the use of ventilated trays which also affords greater mechanical protection.

Certain conditions may call for the use of totally enclosed tray systems. Local building codes should be examined to specify the type of tray bottom to be used.

In areas where control or data cables need protection from RFI interference electromagnetic shielded tray may be used.

C. FITTINGS

In the majority of instances the construction and outside diameter of the largest cable will determine the radius of the fittings to be used. Changes in direction in either the horizontal or vertical planes as well as tray size are accomplished by fittings. The maximum open spacing between transverse rungs in a ladder fitting should not exceed 100 mm as measured in a direction parallel to the siderails of the fitting. The two major decisions to be made regarding a fitting are: degrees (30, 45, 60 and 90) and radius [305 mm (12"), 610 mm (24"), 915 mm (36"), 1220 mm (48")].

i. **DEGREES OR SECTORS:** The sector is that portion of a circle described by the fitting. Standard sectors are 30, 45, 60 and 90 degrees. A 45 degree fitting is 1/8 of a circle.

ii. **RADIUS:** is the distance from the center of the circle to the inside siderail of the fitting. The decision with respect to the radius is a complex one based on a compromise between cost, ease of cable installation (pulling) and the available space. The minimum radius should equal the minimum bending radius of the cables. Depending on the number of cables to be placed in the system it may be advantageous to use the next highest radius. If a standard fitting will not work, adjustable fittings can be ordered direct from our factory. Additional supports may have to be added to these points. The CSA standard currently does not publish fitting support criteria. As it now stands, current practice is the supporting of fittings to limit visual deflection of the fitting. We have previously relied on the NEMA V-2 installation recommendations. Extensive testing on Unitray's standard fittings demonstrated that in addition to NEMA V-2 recommendations, standard fittings can safely be installed using any of the installation alternatives for support locations referenced in DIAGRAMS D.18 through D.24 in the INSTALLATION GUIDE booklet.

D. CSA LOAD CLASS

Currently there are four (4) load classes listed by CSA. These categories address both maximum support spacing and load ratings. **SEE FIGURE D.1.** The latter expressed as kilograms per meter must include: total cable weight, accessories, and covers as well as any outdoor factors the tray will be subject to (eg. wind and snow loads). Outdoor factors may substantially reduce the actual cable load capacity of the tray.

FIGURE D.1

CSA STANDARD LOAD CLASSES *(SEE CLAUSE 4.3 AND 6.1.3)*
DESIGN LOAD AT VARYING SUPPORT SPACINGS IN KG/METER

CLASS	1.5 m	2.0 m	2.5 m	3.0 m	4.0 m	5.0 m	6.0 m
A	99	62	45	37	N/A	N/A	N/A
C1	259	164	119	97	N/A	N/A	N/A
D1	N/A	N/A	N/A	179	113	82	67
E	N/A	N/A	N/A	299	189	137	112

CSA 22.2 number 126-M1991

PREVIOUS LOAD CLASS RATINGS
MAXIMUM DESIGN LOAD FOR MAXIMUM ASSOCIATED SUPPORT SPACING

CLASS	DESIGN LOAD (kg per m)	DESIGN SUPPORT SPACING METERS
A	37 kg/m	3 m
C1	9 kg/m	3 m
D1	67 kg/m	6 m
E	112 kg/m	6 m

CSA 22.2 number 126-M1980

CLASS A: is for light duty applications normally used with small control wiring instrumentation/communication.

CLASS C: used where long spans are not feasible. Maximum support span of 3 meters providing for normal applications.

CLASS D: used where long support span of 6 meters and long runs will provide heavy duty applications and economic advantages.

CLASS E: used in extra heavy duty applications on 6 meter support as it carries 67% more loads than “D”.

i. **TOTAL CABLE LOAD:** This is the total weight of cables in the tray. Calculate the total cable weight per foot, including any future requirements. To select a suitable tray this cable weight should be rounded off to the next higher CSA class.

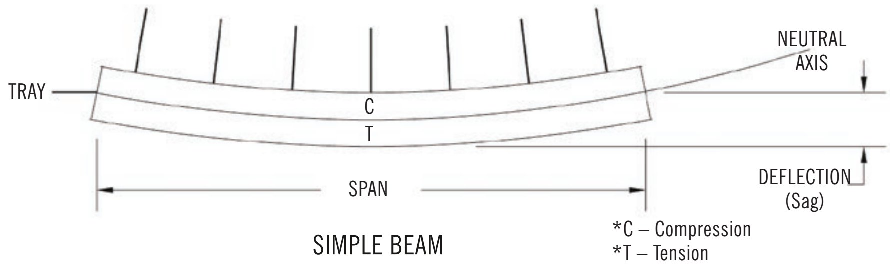
ii. **OUTDOOR FACTORS (wind, snow and ice):** These factors should be considered when the tray system or part of the system is installed outdoors. Snow and ice load calculations are especially important when the tray is covered. As a rule of thumb the following loads may be used for outdoor applications:
   a) 12 – 13 mm of ice on all surfaces weighs on average 1.1 kg/.09 sq. meter of surface area.
   b) 120 kms/hour of wind = 11.1 kg/.09 sq. meter pressure. Snow loads are dependent upon the latitude and altitude of the particular job site. Therefore, the designer should consult the local weather bureau to establish known historical snow loads per square meter. Snow is considered to be a uniformly distributed load.

E. SPAN (Support Spacing)

Do not confuse span with tray length. The distance between supports is called SPAN. The support span should not be greater than the length of the tray. This will prevent two (2) connecting points from being located within one support span. When tray is supported as a simple beam, the load causes bending moments all along the beam resulting in downward vertical deflection inducing stress in the beam. Material above the neutral axis (center line) is compressed, while the material below is in tension (stretched).

See FIGURE E.1. The center of the span in a simple beam contains the maximum stress.

FIGURE E.1



Under the current CSA standard clauses 4.3 and 6.1.3, it is now possible to vary the maximum design load for tray as a function of its support span. This allows for heavier tray loading if the support span is reduced up to one half of the maximum support span. Often times the tray support system has been designed to serve as a number of purposes, resulting in a greater number of supports than the tray system requires. The designer is able to: 1) load his tray more heavily, 2) make more extensive use of 152 mm (6") high tray and 3) reduce the number and width of tray in his system design. By loading this tray more heavily, the designer must be careful not to exceed the total cable capacity as outlined in the Canadian Electrical Code (See following section on ladder tray sizing).

i. **THERMAL EXPANSION AND CONTRACTION:** When installing ladder tray systems, one must consider thermal movement. Long ladder tray runs are particularly susceptible to extreme variations of temperature in northern climates. Different materials have different coefficients of linear expansion. This coefficient should be multiplied by the length of the tray run and the possible temperature variation (high vs. low) at the project site to determine the amount of the expansion/ contraction for a given run. If it is determined that expansion connectors [ECA) - (*)] are required FIGURE E.2 should be used for determining the maximum spacing between expansion joints. Aluminum tray, due to it's high coefficient of expansion, may require a expansion joint at every third (3rd) tray.

FIGURE E.2
MAXIMUM SPACING BETWEEN EXPANSION JOINTS THAT PROVIDE FOR 25 mm OF MOVEMENT

TEMPERATURE DIFFERENTIAL		STEEL		ALUMINUM	
CELSIUS	FAHRENHEIT	METER	(FT)	METER	(FT)
-45	(23)	156	(512)	79	(260)
10	(50)	78	(256)	40	(131)
25	(77)	52	(171)	27	(89)
40	(104)	39	(128)	20	(66)
50	(122)	31	(102)	16	(52)
65	(150)	26	(85)	13	(43)
80	(176)	22	(72)	11	(36)

The tray should be fixed securely at a support nearest to its mid point between expansion connectors. The tray run should be allowed longitudinal movement in both directions from fixed points towards expansion connectors.

At the time of installation, an accurate gap setting is necessary to ensure proper operation of the expansion connectors. To determine the correct gap setting the following steps should be followed with reference to FIGURE E.3

STEP 1. Mark on the Y Axis the highest expected metal temperature.

STEP 2. Mark on the Z Axis the lowest expected metal temperature.

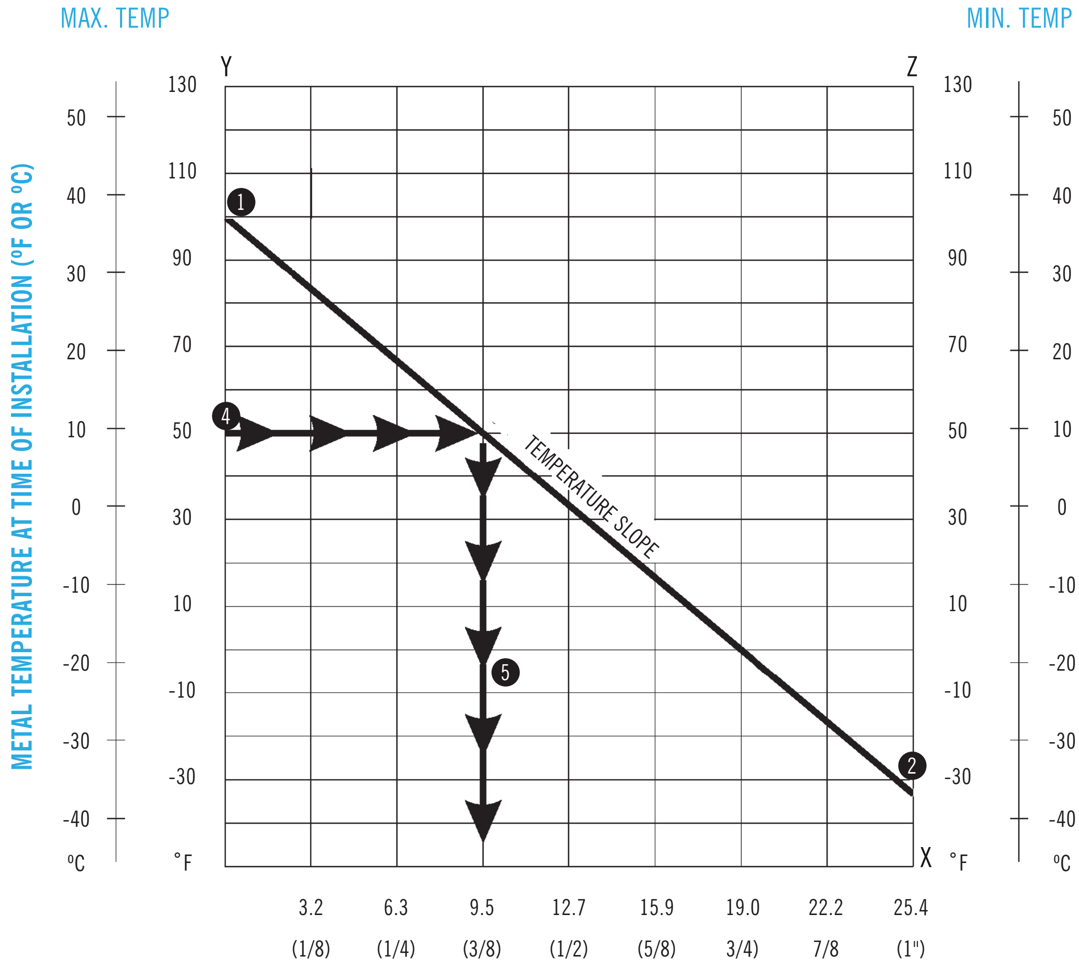
STEP 3. Draw a straight line connecting 1 to 2.

STEP 4. Mark on the Y Axis the temperature at time of installation. Draw a horizontal line from that point connecting line 1 to 2.

STEP 5. From that intersection point draw a straight line down to the bottom Axis X.

STEP 6. That point will give required gap setting at time of installation.

FIGURE E.3



GAP SETTING mm (inches)
GAP SETTING OF EXPANSION CONNECTOR PLATES 25.4mm (1") GAP MAXIMUM

F. DEFLECTION

Deflection is the vertical sag of the tray at its mid point and is at right angles to the tray's longitudinal axis. The issue of deflection is not one of a structural nature, but a cosmetic (appearance) one. Unless the tray run is at eye level or located in a prominent location, it is not considered good engineering practice nor economical to restrict deflection of ladder tray. Ladder tray that meets all dimensional and performance criteria with a safety factor of 1.5 without regard to deflection is the most economical tray. One may limit deflection in a specific tray run, the entire tray system and given location.

The various methods of reducing deflection in ladder tray in order of decreasing costs are:

i. Reducing span length and at the same time increasing field labor and the cost of material for extra supports. This is not practical for the entire system, but is a good idea for short tray runs.

ii. The use of steel vs. aluminum. Aluminum has a modulus of elasticity of 70,000 MPa. Steel is approximately three (3) times greater. Therefore given the same load, aluminum will deflect almost three times more than steel.

iii. Increasing the strength of the siderail by adding more material to the unit and therefore increasing the cross sectional area while maintaining the height of the siderail is another means. However, this method, while limiting deflection, increases the cost of the tray dramatically.

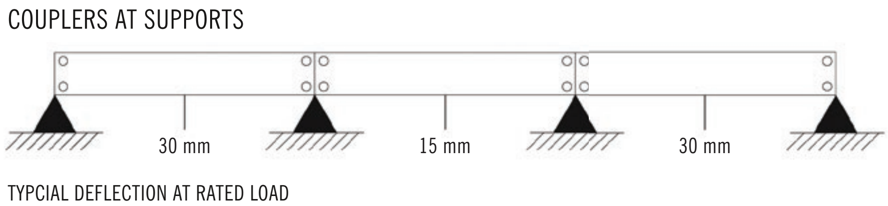
iv. The final and most effective method is via the design/placement of the supporting structures for the tray. There are two methods where by the bending movements on the tray are reduced by decreasing the stresses. The first method is by the use of rigid supports at the end of the tray spans that provide restraining movements (e.g. fixed beam loading bracket). The second method is by the creation of continuous beam loading. The supports are not placed at the ends of each tray sections, but instead are located at a distance no greater than 1/4 of the length of the tray (e.g. 1.5 meters for a 6 meter tray). Each tray ends up with one support. The resultant negative bending movements at the intermediate supports in the continuous beam support system is a fraction of the simple beam deflection. Continuous beams will deflect on average 42% of that of simple beams.

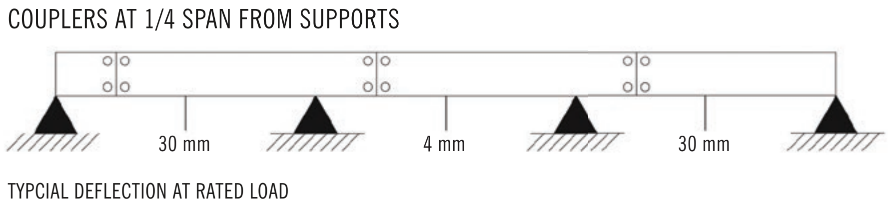
1. LOCATION OF CONNECTORS

Connector location has a pronounced effect on the ladder tray system under equal loading conditions. The current standard recommends connector location to be located within one quarter (1/4) of the span from the supports. This is the ideal location. Unspliced straight sections should be used on all simple spans and on end spans of continuous span arrangements. A support should be located within 0.6 meters (2') of each side of an expansion connector.

As the connector is moved away from the 1/4 span location, the deflection of the tray increases. On a three (3) span run of tray deflection of the center span may increase three (3) to four (4) times if the connectors are moved from 1/4 span to above the supports. See FIGURE F.1

FIGURE F.1

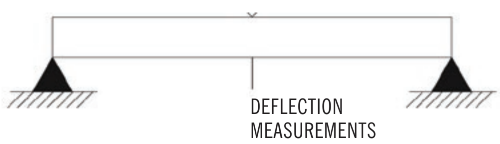




2. CSA LOAD TEST

Any material length in a horizontal position placed on a support at either end is a SIMPLE BEAM. A uniformly distributed load on a simple beam is the test method used by CSA. See FIGURE F.2

FIGURE F.2



When a series of straight sections of tray are connected and supported by more than two supports it is a CONTINUOUS BEAM. CSA uses the simple beam for the following reasons:

- it represents the most severe loading situation **(worst case scenario)**
- it is the easiest to approximate by calculation
- it represents the maximum properties for a given load and support spacing
- destructive load testing and capacity is easily verified by test and can be reliably repeated

There are two criteria for acceptance under CSA:

1. The ability of the tray to support 150% of its rated load and
2. A residual deflection (after all test weights have been removed) of less than 80% of the initial deflection (10% of test load).

CONTINUOUS VS. SIMPLE BEAM DEFLECTION (SEE FIGURE F.2.2)

Using the below factors where:

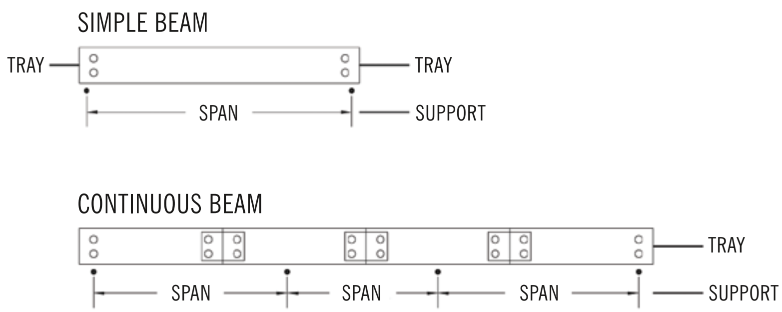
W = Load lbs/ft
L = Length (inches)
I = Movement of Inertia
E = Modulus of Elasticity

One may calculate maximum deflection for uniformly distributed loads in:

1. A simple beam using the formula .0130 x WL^4/EI.
2. A continuous beam using the formula .00541 x WL^4/EI.

In other words a two (2) span continuous configuration has a theoretical maximum deflection on average 41.6% of its simple beam configuration.

FIGURE F.2.2



The tray will behave more like a fixed beam as the number of spans increases and the resultant maximum deflection will continually decrease. Subsequently the load carrying capacity of the tray system will increase. There is no hard or fast rule to determine actual deflection when the number of spans increases and different bending moments are created in each span. To approximate the deflection of internal spans of a continuous beam tray system one may use a factor of 12% of the deflection numbers in a simple beam system.

G. MATERIALS

1. MATERIALS AND FINISHES

Under the current CSA standard, stainless steel and non-metallic tray now qualify for use as ladder tray material. They join galvanized steel and aluminum as material types. Galvanized steel is now split in two (2) categories. TYPE I AND TYPE II.

a. ALUMINUM

MATERIAL SPECIFICATION

- 6063, 6061 extrusions used on the siderails and rungs.
- 5052 – H32 used for solid tray, covers and accessories.
- 3105 – H12 (optional) used for cover and accessories.
- Contains portions of silicon and magnesium forming magnesium-silicide/silicon (Copper Free).

ADVANTAGES

- **Light** – Volume for volume aluminum weighs 35% less than steel. Easier to install, resulting in low installation costs.
- **Strong** – Properly alloyed aluminum can be as strong as some steels.
- **High in Strength - to - Weight Ratio** – A superb combination of strength and lightness. This ratio is measured by a material's ultimate tensile strength divided by its density (weight per unit volume). Helped build modern aerospace industry.
- **Resilient** – Can deflect under loads and shocks, and spring right back. Protects not only the product's form, but can be built in when flexible strength is required.
- **Corrosion Resistant** – Does not rust. Exposed surface combine with oxygen to form an inert aluminum oxide film, blocking further oxidation. If scratched it instantly seals itself with a new layer. Properly alloyed it resists corrosion by water, salt, environmental factors and many chemical and physical agents.
- **Non-toxic** – Solid aluminum is non-toxic. Smooth, non-porous, easily cleaned surface. Used in food preparation and packaging since it will not absorb bacteria.
- **Reflective** – Highly reflective (plus 80%) of both visible light and visible radiation. Reflective both as a shield as a reflector of light, radio waves and infrared (heat) radiation.
- **Heat Reflective** – Conducts heat better than any other common metal on both a cost and weight basis.
- **Conductivity** – Volume for volume, carries electricity about 62% as well as copper. On equal weight basis can be twice as conductive as copper. Often the most economical choice for electrical system components. Used almost exclusively in bulk power transmission.
- **Non-Sparking** – Though as excellent conductor, it does not produce sparks. Essential property when used with explosive material and highly flammable environments.
- **Non-Magnetic** – Useful for high voltage hardware, for use in strong magnetic fields and around sensitive magnetic devices. Minimal electrical losses.
- **Recyclable** – Large and active secondary market exists for scrap aluminum products. Aluminum has a substantially higher scrap value. Appeals to buyer's pocket book and concerns for environmental protection.
- **Cold Strength** – Aluminum is not impaired by cold. Aluminum gains strength as temperature is reduced.
- **Noncombustible** – Solid aluminum does not burn and generates no hazardous emissions when exposed to heat.

b. STEEL

Carbon steels have different grades and quality variations. Cold forming (rolling and bending) increases the mechanical strength of the steel allowing a high strength to weight ratio. All carbon steels used in ladder trays must have a protective coating of zinc applied. Steel ladder tray has load thermal expansion (low coefficient) and provides electric shielding for low level control circuits when used in electro-magnetic shielded ladder trays.

TYPE I – HOT DIP GALVANIZED AFTER FABRICATION

- Specification CSA standard G164 or ASTM 123 with a minimum zinc coating of 1.4 mils or 260 grams/sq. meters (0.85 oz /sq.ft) for 16 gauge and a minimum zinc coating of 2.22 mils or 400 grams/sq. meter (1.31 oz/sq.ft) for 12 gauge.
- After fabrication tray is dipped into a bath of molten zinc.
- The thickness of the coating is dependent upon: 1) Time in the bath and 2) The speed of removal.
- Holes for connecting plates may be under sized as a result of the extra coating of zinc.
- Thickness of the coating may vary.
- Depending on the rung (cross member) profile and its placement on the siderail the contact surface between the two members may have less zinc coating than the rest of the tray.
- There may exist a rough finish that may damage the sheathing of the electrical cables.
- Recommended for outdoor applications particularly in chlorine or caustic environments.
- Sometimes a lower cost product to purchase is often times offset by higher installation costs due to heavier weight.

TYPE II – PRE-GALVANIZED OR MILL GALVANIZED G-90

- Specification ASTM A653R maintaining an average of .45 ounces of zinc per square foot per side.
- Produced at the mill by feeding sheet stock from a coil through molten zinc.
- Steel is then recoiled and slit to a specific size.
- During the slitting process and shop fabrication cut edges are protected via the electrolytic action of adjacent zinc surfaces.
- Generally recommended for dry indoor applications.

c. STAINLESS STEEL

Stainless steel is a generic term for a family of corrosion resistant alloy steels containing 10.5% or more chromium. All stainless steels have a high resistance to corrosion due to the naturally occurring chromium-rich oxide formed on the surface of the steel. This film is extremely thin, invisible, inert and tightly adherent to the metal. It is extremely protective in a wide range of corrosive media. This coating is rapidly self repairing in the presence of oxygen and damage by abrasion cutting or machining is quickly repaired. It is vital to preserve it's integrity by avoiding mechanical damage and contamination. Repair any affected areas (contaminated areas) by passivation only or by both passivation and pickling; and ensure a constant and sufficient oxygen availability at its surface. In addition to chromium; nickel, molybdenum, titanium, niobium and other elements may also be added to stainless steel to produce a range of different grades, each with different properties. These can be grouped into 5 basic categories.

- Austenitic } *Account for approximately 95% of applications.*
- Ferritic
- Duplex
- Martensitic
- Precipitation hardening

There are two types of stainless steel used in the manufacturing of ladder tray. They are 304 and 316. Both types are austenitic and possess the following basic properties.

- Excellent corrosion resistance
- Excellent weld ability (all processes)
- Excellent formability, fabricability and ductiblity
- Excellent cleanability and hygiene characteristics
- Good high and low temperature properties
- Non magnetic (if annealed)
- Hardenable by cold work only

i. TYPE 304
Is comprised of 18% chromium and 8% nickel with a maximum carbon content of .08%. Generally 304 is the most economical of the two and the most commonly specified of all the grades by far. It also shows good corrosion resistance in the “as-welded condition” (up to approximately 55 – 60% at 100º C (212º F). It is very effective against inorganic and organic chemicals.

ii. TYPE 316
Contains more molybolemium and nickel in order to resist pitting and crevice corrosion. This type of stainless has better resistance to acidic environments such as sulphuric and chloride.

The benefits of using stainless steel are as follows:

- **Corrosion Resistance** – All stainless steels have a high resistance to corrosion. Low alloyed grades resist corrosion in atmospheric conditions, highly alloyed grades can resist corrosion in most acids, alkaline solutions, and chloride environments even at elevated temperatures and pressures.
- **High and Low Temperature Resistance** – Some grades will resist scaling and maintain high strength at very high temperatures, while other grades show exceptional toughness at cryogenic temperatures.
- **Ease of Fabrication** – Majority of stainless steels can be cut, welded, formed, machined and fabricated readily.
- **Strength** – The cold work hardening properties of many stainless steels can be used in design to reduce material thicknesses and reduce weight and costs.
- **Aesthetic Appeal** – Since stainless steel does not rust it requires no painting. It is available in many surface finishes. It is easily and simply maintained resulting in a high quality, pleasing appearance.
- **Hygienic Propertie**s – The cleanabilty of stainless steel makes it the first choice in hospitals, kitchens, food and pharmaceutical processing facilities.
- **Life Cycle Characteristics** – Stainless steel is a durable, low maintenance material and is often the least expensive choice in a life cycle (cradle to grave) cost comparison.

It is 100% percent recyclable preferred raw material input by steel makers. New stainless steel comprises at least 50% recycled stainless steel product. There are some key considerations in working with stainless steel:

- **Know the Material** – Knowledge improves decision making, avoids problems and saves costs.
- **Thermal Conductivity** – Stainless steel has a much lower conductivity than that of carbon (mild) steel (plain chromium grades approximately 1/3 and austenitic grades approximately 1/4). This must be kept in mind for any operation which involves high temperature. Effects during welding (control heat input), longer times are required for heating to attain a uniform temperature for hot working.
- **Expansion Coefficient** – Plain chromium grades have an expansion coefficient similar to carbon (mild) steels, but that of the austenitic grades is about 1–1/2 times higher. The combination of high expansion and lower thermal conductivity means that precautions must be taken to avoid adverse affects. During welding use low heat input, dissipate heat by the use of copper backing 18 bars and use adequate jigging.
- **Seizing and Galling** – Stainless steels have a tendency to seize or gall. Take the following precautions: for surfaces undergoing relative motion minimize the load, keep free of dirt and contaminants, insure no heat build up and use surface coatings or lubricants. For threaded components insure that the threads have a high degree of surface finish. Components should have an intermediate to free fit and avoid the over-torquing and contamination of the threads.

d. OTHER SUPPLEMENTARY COATINGS SUCH AS PVC (POLYVINYCHLORIDE) AND EPOXY ARE AVAILABLE.

A PVC coating is recommended on bare steel tray and aluminum tray. PVC is not recommended as coating on galvanized steel tray due to rough surfaces and gas emissions which may cause poor adhesions and voids. Other supplementary coatings may be applied. However, these as well as PVC and epoxy coatings do not fall within the scope of the current CSA NO. 126 Standard. If material applicability was not an issue in the design of ladder tray, most designers would choose pre-galvanized (TYPE I) material. In many respects it would be the most cost effective. However, for the majority of designers there are other material requirements affecting the design such as:

2. DEFLECTION

In most cases deflection of the ladder tray is a cosmetic one. In the case of non-metallic tray elevated temperatures will affect deflection. Aluminum tray will deflect (depending on support location) more than steel.

3. WEIGHT

The following costs: i) required support system ii) material handling and iii) installation of the system will be affected by the weight of the system.

4. FLAMMABILITY RATING OR MELTING POINT

Is a consideration primarily for non-metallic trays. Local building codes may govern via performance criteria whether certain materials may be used.

5. RELATIVE COST

Is a factor which changes substantially. Here the engineer would specify the cheapest material which fulfills the requirements of the application. The majority of material costs being linked to the commodity index, will often times show tremendous cyclical movements.

6. CORROSIVE RESISTANCE

Of the tray material is often times one of the main selection criteria. All metal surfaces that are exposed to the environment are affected by corrosion. Materials do not respond in a similar manner to different corrosive environments (see the following CORROSION CHART A). The designer must make the final selection based on his knowledge of the various chemical elements affecting his system. There are five (5) main types of corrosion:

i OVERALL OR GENERAL CORROSION
This is an attack in a uniform fashion over the entire exposed area of a surface across a wide range of temperatures.

ii. MICROBIOLOGALLY INDUCED CORROSION (MIC)
This occurs when a surface of a metal is exposed to untreated watery substances that contain living microbial organisms. There is a tendency for these organisms to form colonies on the surface of the metal, especially on areas that contain surface irregularities (e.g. welded joints) leading to corrosive conditions.

iii. STRESS-CORROSIVE CRACKING (SCG)
This occurs when a stressed metal is exposed to certain types of environments. Stresses are generally tensile in nature and may be either applied or residual. These stress exposed metals may become susceptible to SCG. This act of nature involves stresses that may be significantly below the yielding strength of the material.

iv. PITTING CORROSION
This occurs when localized areas of the surface passive layer are damaged (common for aluminum and stainless steels exposed to chlorine). The passive layer is no longer able to protect the under laying metal against attack. Pits can then form, which can lead to high localized corrosion rates with little or no general corrosion to the surrounding areas.

v. GALVANIC CORROSION
If two dissimilar metals are electrically connected and exposed to an electrolyte, the more electrochemically active metal corrodes by galvanic action at an increased rate. Galvanic effect may still result in a corrosive product even though the parent material of the tray system is resistant to it's environment. As mentioned above, two (2) dissimilar metals in contact may create a galvanic effect (e.g. stainless steel tray on pre-galvanized strut). The expensive solution would be one of using a support system constructed entirely of stainless steel. A more viable alternative would be isolating/ separating the tray system from other systems by way of an isolator.

Galvanic corrosion potential (GCP) is a measure of how dissimilar metals when placed against one another in an assembly will corrode. The farther apart any two metals are on the chart, the stronger will be the corroding effect on the higher one in the list. The closer two items are to one another, the smaller will be the GCP on each other. This chart simply represents the potential available to promote galvanic corrosion. The effect and the degree of actual corrosion is difficult to predict. To promote galvanic corrosion the presence of water (or other electrolyte) is generally required.

GALVANIC CORROSION POTENTIAL (GCP) CHART

ANODIC (LEAST NOBLE) CORRODED

ELECTRIC CURRENT FLOWS FROM PLUS TO MINUS

Arrows show direction of attack.

CATHODIC (MOST NOBLE) PROTECTED

Magnesium
Magnesium Alloys
Zinc
Beryllium
Aluminum 1100, 3003, 3004, 5052, 6053
Cadmium
Aluminum 2017, 2024, 2117
Mild Steel 1018, Wrought Iron
HSLA Steel, Cast Iron
Chrome Iron (active)
430 Stainless (active)
302, 303, 321, 347, 410, 416 Stainless Steel (active)
Ni-Resist
316, 317 Stainless (active)
Carpenter 20Cb-3 Stainless (active)
Aluminum Bronze (CA687)
Hastelloy C(active Inconel 625 (active)
Titanium (active)
Lead/Tin Solder
Lead
Tin
Inconel 600 (active)
Nickel (active)
60% Ni 15% Cr (active)
80% Ni 20% Cr (active)
Hastelloy B (active)
Naval Brass (CA464), Yellow Brass (CA268)
Red Brass (CA230), Admiralty Brass (CA443)
Copper (CA102)
Manganese Bronze (CA675), Tin Bronze (CA903, 905)
410, 416 Stainless (passive) Phosphor Bronze (CA521, 524)
Silicon Bronze (CA651, 655)
Nickel Silver (CA732, 735, 745, 752, 754, 757, 765, 770, 794)
Cupro Nickel 90-10
Cupro Nickel 80-20
430 Stainless (passive)
Cupro Nickel 70-30
Nickel Aluminum Bronze (CA630, 632)
Monel 400, K500
Silver Solder
Nickel (passive)
60% Ni 15% Cr (passive)
Iconel 600 (passive)
80% Ni 20% Cr (passive)
Chrome Iron (passive)
302, 303, 304, 321, 347 Stainless (passive)
316, 317 Stainless (passive)
Carpenter 20 Cb-3 Stainless (passive), Incology 825 (passive)
Silver
Titanium (passive), C & C276 (passive)
Graphite
Zirconium
Gold
Platinum

CORROSION CHART A: The following chart cannot cover all the variables of aeration, impurities, temperatures and concentrations. It should be used for general comparison only in selecting materials for use in a known condition. More extensive information should be sought. If that information cannot be sourced; then field service tests or simulated laboratory tests should be conducted to determine proper materials and finishes to be selected.

A: Excellent B: Good C: Fair D: Unsatisfactory

	Aluminum	Brass	Steel	Monel	316 SS	Polyethylene	Neoprene	Incone1	Carp-20	Hastelloy C	Titanium
Acetaldehyde	A	A	C	B	A		D	B		A	
Acetic Acid	B	D	D	C	A	C	C	B	C	A	A
Acetic Anhydride	A	D	D	A	B		C	A			
Acetone	B	A	B	A	A	C	C				A
Acetylene	A	B	A	A	A		A	A			A
Acrylonitrile	B	A	A	A	A		D	A		A	A
Alcohols	B	B	B	A	A	B	A	A			A
Aluminum Chloride	D	D	D	B	D	B	B	D		A	
Aluminum Fluoride	A	D	D	B	C	B				B	B
Aluminum Hydroxide	B	B	B	B	B					B	A
Aluminum Sulfate	C	D	D	B	C	B	A	D		A	A
Amines	B	B	B	A	A		D	B	B	A	A
Ammonia Anhydrous	B	D	A	A	A	B	B	A	A	A	
Amm. Bicarbonate	B	D	B	D	B	A	A	D			A
Amm. Carbonate	B	C	B	B	B		A	B		B	
Ammonium Chloride	D	D	C	B	B	B	A	B	B	A	A
Ammonium Hydroxide	B	D	B	D	A	B	A	A		A	A
Amm. Monophosphate	B	D	D	B	B	A	A				
Ammonium Nitrate	B	D	A	C	A	B	A			B	C
Ammonium Phosphate	A		A	A	A		A				
Ammonium Sulfate	D	D	C	B	B		A	B		B	A
Ammonium Sulfite	D	D	D	C	B			D			
Amyl Acetate	A	B	A	A	A		D	A		A	A
Aniline	B	D	A	B	A		C	B		B	A
Apple Juice	B	C	D		B		A				
Arsenic Acid	D	D	D	B	B		A	A		B	
Asphalt	A	B	A	A	A		C				
Barium Carbonate	D	A	B	B	B	A	A			B	A
Barium Chloride	B	B	B	B	B	B	A	A		B	B
Barium Hydroxide	D	D	B	B	A	B	A	B		B	A
Barium Nitrate	B	D	B	C	B	B		B	B		
Barium Sulfate		B	B	B	B	B	A	B		B	
Barium Sulfide	D	D	A	D	A	B	A				A
Beer	A	B	C	A	A		A				
Beet Sugar Liquor	A	C	B	A	A		A				
Benzene	B	B	B	A	B		D	A		B	A
Borax	C	C	B	A	A	B	A				
Black Sulfate Liquor	D	B	A		A		A				
Boric Acid	B	B	D	B	B	B	A	B		A	A

	Aluminum	Brass	Steel	Monel	316 SS	Polyethylene	Neoprene	Incone1	Carp-20	Hastelloy C	Titanium
Brine			C	A	B		A	A		A	A
Bromine Dry	B	D	D	C	D	B	D	D		D	D
Bromine Wet	D	D	D	C	D	D	D	D	D	D	D
Bunker Oil	A	B	B		A		B				
Buttermilk	A	D	D	A	A		A				
Butyric Acid	B	D	D	B	B	B	C	C		A	A
Cal. Bisulphite	D	D	D	D	A			D		A	A
Cal. Carbonate	C	B	A	B	A	A	A	B		B	A
Cal. Chloride	B	B	B	A	B		A	A	B	A	A
Cal. Hydroxide	C	D	B	B	B		A	B		A	A
Cal. Hypochlorite	D	D	C	C	C		B	D		B	A
Calcium Sulphate	B	B	B	B	A		A	D			A
Carbolic Acid	B	C	C	B	A		D	B		A	A
Carbon Bisulfide	A	C	B	B	B		D				A
Carbon Dioxide	A	A	A	A	A	B	B	A	A	A	A
Carbonic Acid	A	A	D	A	A	B	A	A			A
Carbon Tet-Wet	D	B	D	A	A	C	D	A		A	A
Carbon Tet-Dry	A	C	D	A	B		D	A		A	A
Carbonated Water	A	B	B		A		A	A			A
Castor Oil		A	A	B		A	B				
Chlorinated Solvent	A	A	A	A	A		D	A	A	A	A
Chloric Acid		D	D	D	C	C				A	A
Chlorinated Water	D	D	D	A	C					A	A
Chlorine Gas-Dry	D	D	B	A	B	C	C	D		A	A
Chlorine Gas-Wet	D	D	D	B	C	C	D	B		D	A
Chloroform-Dry	A	A	A	A	A		D	A		B	A
Chlorosuphonic-Dry	A	D	A	C	B		D	C		A	D
Chlorosulphonic-Wet	D	D	D	D	D		D	C		A	
Chromic Aluminum	C	C	B		A		B				
Chrome Acid		D	D	B	D	D	B	D	B	B	A
Citric Acid		B	D	D	B	C		A	A		
Coconut Oil	A	C	C	B	A		B	A		A	A
Coke Oven Gas	A	C	B		A		C	A			
Copper Acetate	D	D	C	A	B			A		B	A
Copper Chloride	D	D	D	B	D		A				
Copper Nitrate	D	D	D	D	B	B	A	D		B	A
Copper Sulfate	D	B	D	B	B			B		A	B
Corn Oil		D	D	D	D	A	B	A			
Cottonseed Oil	B	B	C		B		B				
Creosote		B	B	B	A	B	D	D	A		B
Crude Oil, Sweet	A	B	B		A		B				
Diesel Fuel	A	A	A		A		C	A	A	A	A
Diethylamine	B	D	A	B	A		C	A		A	A
Dowtherm	A	A	B		A		D				
Drying Oil	C	C	C		B		B				

	Aluminum	Brass	Steel	Monel	316 SS	Polyethylene	Neoprene	Incone1	Carp-20	Hastelloy C	Titanium
Epsom Salt	A	B	C		B		A	A	A	A	A
Ethane	A	A	A	A	A		B	A	A	A	A
Ethers		A	B	A		A		C			
Ethyl Acetate	A	B	A	A	A		D	A		A	A
Ethyl Alcohol	B	A	A	A	B		A	A	A	A	A
Ethyl Chloride - Dry	B	B	A	B	A	D	C	A		B	A
Ethyl Chloride - Wet	B	B	D	B	A		C	A		B	A
Ethylene Glycol	A	B	A	A	A	B	A	A		A	A
Ethylene Oxide	A	A	A	A	A		D	A		A	A
Fatty Acid	A	C	B	B	A		B	A		A	A
Ferric Chloride	D	D	D	D	D	B	A	D		B	A
Ferric Nitrate	D	D	D	D	B	B	A	D		B	
Ferric Sulfate	D	D	D	D	B	B	A	A		A	A
Ferrous Chloride	D	D	D	D	D		A	D		B	A
Ferrous Sulfate	C	D	D	B	B	B	A	B		B	A
Fish Oils	B	B	B		A		B				
Fluorine-Dry	B	C	A	A	B	B		A		B	D
Fluorine-Wet	D	D	D	A	D	B	C	A		B	D
Fluroboric Acid	D		A	A	A			A			D
Fluorosilicic Acid	D	A	D	A	A		C	A	B	B	D
Formaldehyde Cold	A	A	A	A	A		B	B		B	A
Formaldehyde Hot	B	B	D	B	B		B	B		B	A
Formic Acid Cold	A	B	D	C	B		A	C	A	A	D
Formic Acid Hot	D	B	D	D	B		A	D	B	B	D
Freon	B	B	C	A	C	B	C	B		B	C
Fuel Oil		A	A	A	A	A		B			
Furfural	B	B	B	B	B	D	C	B		B	B
Gasoline	A	A	A	A	A	D	D	A		A	A
Gas, Manufactured	B	B	B		B		A	A		A	A
Gas, Natural	A	A	A	A	A		A	A	A	A	A
Gas Odorizers	A	A	B		B		A				
Gelatin		A	A	D		A		A	A		
Glucose	A	A	B		A		A	A	A	A	A
Glue	A	B	A		B		A	A	A	A	A
Glycerine	A	A	A	A		D	A	A	A	A	A
Glycols	A	A	A	A	A		A	A	A	A	A
Grease	A	A	A	A	A		B	A	A	A	A
Heptane	A	A	A	A	A		B	A	A	A	A
Hexane	A	A	A	A	A		C	A	A	A	A
Hydraulic Oil	A	A	A	A	A		B	A	A	A	A
Hydrobromic Acid	D	D	D	D	D		C				A
Hydrochloric Acid	D	D	D	B	D	B	C	D	D		D
Hydrocyanic Acid	A	D	A	B	A		B	A		B	A
Hydrofluoric Acid	D	D	D	B	D	C	C	D		B	C
Hydrogen Gas-Cold	A	A	A	A	A		B	A	A	A	A

	Aluminum	Brass	Steel	Monel	316 SS	Polyethylene	Neoprene	Incone1	Carp-20	Hastelloy C	Titanium
Hydrogen Cl-Dry	D	C	B	A	B	B		A		A	
Hydrogen C1-Wet	D	D	D	C	D			A			
Hydrogen Perox-Diluted	A	D	D	B	B	B	A	B		A	A
Hydrogen Perox-Concentrated	A	D	D	D	A		D	A		A	A
Hydro Sulfide-Dry	B	B	B	B	A	B	A	B		B	A
Hydro Sulfide-Wet	B	D	C	A	A	B	A	B		B	A
Hydrofluosilicic	D	D	D	A	C	B	A				
Illuminating Gas	A	A	A	A	A		B	A		A	A
Ink	C	C	D		A		A				
Iodine	D	D	D	B	B	C	B	D		B	D
Iodoform	A	A	A	B	A			B		B	A
Isooctane	A	A	A	A	A		C				A
Isopropyl Alcohol	B	B	A	A	A		C	A		A	A
Isopropyl Ether	A	A	A		A		C				A
JP-4 Fuel	A	A	A		A		C				A
JP-5 Fuel	A	A	A		A		C				A
JP-6 Fuel	A	A	A		A		C				A
Kerosene	A	A	A	A	A	B	C				A
Ketchup	A	A	A		A		A				A
Ketones	A	A	A		A		D				A
Lactic Acid	A	D	D	B	B	B		B		B	A
Lard Oil	A	A	C		B		B				
Magnesium Bisulfate	B	B	C	B	A						
Magnesium Chloride	B	B	B	A	B	B	A	A		A	A
Mag Hydroxide-Cold	D	B	B	A	A	B	A				
Mag Hydroxide-Hot	D	D	B	A	A		A				
Magnesium Sulfate	A	A	A	A	A	B	A	A	A	A	A
Maleic Acid	B	C	B	B	B		A	B		B	A
Malic Acid B	B	D	B	A		A	A			A	
Mayonnaise	D	D	D		A		A				
Melamine Resin	B				B						
Mercuric Cyanide	D	D	B		B					B	A
Mercury	D	D	B	B	A	B	A	A		A	D
Methane	A	A	A	A	A		B	A		A	A
Methyl Acetate	B	B	B	A	A		D	A		A	A
Methyl Acetone	B	A	A	A	A		D				
Methyl Alcohol	B	B	B	A	B		A	A		A	A
Methyl Chloride	D	A	A	B	A	B	C	B			
Methylamine	B	D	B	C	B	B	C	A		B	B
Methyl Ethyl Ketone	A	A	A	A	A		D	B		B	A
Methylene Chloride	A	B	B	B	B	C	D	A		B	A
Milk	A	D	D	B	A	C	A	A			
Mineral Oil	A	A	A	A	A	A	B				
Molasses	A	A	A	A	A	B	A	A			
Muriatic Acid	D	D	D		D		B	D	B		D

CORROSION TABLES (continued)

	Aluminum	Brass	Steel	Monel	316 SS	Polyethylene	Neoprene	Incone1	Carp-20	Hastelloy C	Titanium
Mustard	B	A	B		A		A				
Naphtha	A	A	A	A	A		D	A		A	A
Naphthalene	B	B	A	B	A		D	B			A
Natural Gas	A	A	A	A	A	A		A		A	A
Nickel Chloride	D	D	D	B	B	B	A	D			A
Nickel Nitrate	C	D	B	B	B		A	B		B	A
Nickel Sulphate	D	C	D	A	B	B	A	B		B	
Nitric Acid-10%	D	D	D	D	A		B	D		A	A
Nitric Acid-30%	D	D	D	D	A		C	C		A	A
Nitric Acid-80%	D	D	D	D	A		D	A		D	B
Nitric Acid-100%	D	D	D	D	A		D	A		D	B
Nitric Acid-Anhyd.	D	D	A	D	A		D	A		B	D
Nitrobenzene	A	A	A	A	A		D	A			
Nitrogen	A	A	A	A	A	A	A	A	A	A	A
Nitrous acid-10%	D	D	D	D	B		A				
Nitrous Oxide	C	B	B	D	B		B	D		B	
Oils, Animal	A	A	A	A	A		B				
Oleic Acid	B	B	C	A	B		C	A		A	A
Oleum	B	B	B		B		C	B	A	B	
Olive Oil	A	B	B		A		B				
Oxalic Acid	C	B	D	B	B		A	B		B	D
Oxygen	A	A	B	A	A		A	A	A	A	A
Ozone-Dry	A	D	A	A	A			A			
Ozone-Wet	A	D	C		A			A			
Palmitic Acid	B	B	B	B	A		B	A			
Paraffin	A	A	B			A		B			
Paraformaldehyde	B	A	C	A	A		B	A		A	B
Pentane	A	B	B	B	B		B	B			A
Parez 607		D		D							
Phenol	B	A	A	B	B		D	B		A	A
Phosphoric-10%-Cold	A	B	D	A	B		A	A	A		A
Phosphoric-10%-Hot	A	B	D	A	D		A	D	A		D
Phosphoric-50%-Cold	D	B	D	A	B		B	A	A		D
Phosphoric-50%-Hot	D	B	D	A	D		B	D	A	D	D
Phosphoric-85%-Cold	D	B	B	A	A		B	A	A		D
Phosphoric-85%-Hot	D	B	C	A	A		B	D	A		D
Phthalic Acid	B	B	C	B	A		C	B		B	A
Phthalic Anhydride	A	B	A	A	A		C	B		B	A
Picric Acid	C	D	D	D	B		A			B	
Pine Oil	A	B	B		A		C				
Pineapple Juice	A	C	C		A		A				
Potassium Bisulfite	B	B	D	D	B		A	D		C	
Potassium Bromide	D	A	D	B	B		A	B		B	A
Potassium Carbonate	D	C	B	B	B	B	A	B		A	A
Potassium Chlorate	D	B	C	C	A	B	A	C		B	A

	Aluminum	Brass	Steel	Monel	316 SS	Polyethylene	Neoprene	Incone1	Carp-20	Hastelloy C	Titanium
Potassium Chloride	D	C	C	B	A	B	A	B		B	A
Potassium Cyanide	D	D	B	A	B	B	A	B		B	
Potassium Dichromate	A	B	B	B	A		A	B		B	A
Potassium Diphosphate	B	B	A		A		A				
Potassium Ferricyanide	B	B	C	B	B	B	A	B		B	A
Potassium Ferrocyanide	A	B	A	B	B	B	A	B		B	A
Potassium Hydroxide	D	D	C	A	A	B		A		B	D
Potassium Hypochlorite	D	D	C	D	B			D		B	A
Potassium Permanganate	A	B	B	B	B	B		B		B	
Potassium Sulfate	A	C	B	A	A	B	A	B		A	A
Potassium Sulfide	D	D	D	D	B	B		B		B	A
Propane	A	A	A	A	A		B	A			A
Propyl Alcohol	A	A	A	A	A		C	A		A	A
Pyrogallic Acid	B	B	C	B	B		A	B		B	
Salad Oil	D	D	D	B	A		A				
Salicylic Acid	B	B	D	A	B		A	B		B	
Salt	A	B	C	A	C	B	A	A		A	A
Seawater	B	B	C	A	A	B	A	A		A	A
Silver Bromide	D	D	D	B	D	A				A	A
Silver Chloride	D	D	D	B	D					B	A
Silver Nitrate	D	D	D	D	A	B	C	B		A	A
Sodium Acetate	A	A	A	A	B	B	B	A		A	A
Sodium Aluminate	D	B	A	A	A		A	B		B	A
Sodium Bicarbonate	B	B	B	A	A	A	A	A		A	A
Sodium Bisulfate	B	C	D	B	B	A	A	B		B	A
Sodium Bisulfite	D	D	B	B	A	B	A	B		B	B
Sodium Bromide	D	C	B	B	B	B	A	B		B	
Sodium Carbonate	D	D	A	A	A	A	A	A		A	A
Sodium Chlorate	B	B	B	A	B		A	A		B	A
Sodium Chloride	A	B	C	A	C	B	A	A		A	A
Sodium Chromate	A	A	A	A	A		A	A		A	A
Sodium Cyanide	D	D	A	D	A	B	A	A		A	A
Sodium Fluoride	B	D	D	A	B	B	A			B	B
Sodium Hydroxide	D	D	B	A	A	B	B	A			B
Sodium Nitrate	A	C	A	A	A	B	A	A		A	A
Sodium Perborate	D	D	B	B	A		A	B		B	
Sodium Peroxide	D	D	A	B	B		A	B		B	
Sodium Phosphate	D	A	D	A	B		B	A		A	A
Sodium Silicate	A	A	A	A	A		A	A		B	A
Sodium Sulfate	B	B	B	B	A	B	A	B		B	B
Sodium Sulfide	A	C	C	B	B	B	A	B		B	
Sodium Sulfite	A	D	D	B	A	B		B		B	A
Sodium Thiosulfate	B	D	D	A	A		A	B		B	
Soybean Oil	B	B	C		A		B				
Stannic Chloride	D	D	D	C	D		A	D		B	B

	Aluminum	Brass	Steel	Monel	316 SS	Polyethylene	Neoprene	Incone1	Carp-20	Hastelloy C	Titanium
Starch	A	B	C		B		A				
O Steam-212ºF	B	A	A	A	A		D	A		A	A
Stearic Acid	D	C	C	A	A		C	B		B	B
Styrene	A	A	A	A	A		D	B		A	A
Sulphate, Black Liquid	A	D	B	B	B		A			A	
Sulphate, Green Liquid	D	D	B	B	B		A	B		B	
Sulphate, White Liquid	B	C	C		B		A				
Sulphur	A	D	B	A	A			A		B	A
Sulphur Chloride	D	D	D	C	C			A		A	
Sulphur Dioxide-Dry	A	C	B	B	A		C	B		D	
Sulphur Dioxide-Wet	D	D	D	D	A			B		A	
Sulphur Molten	A	D	B	A	A	D	D				
Sulphur Trioxide	B	B	B	B	B			B		B	
Sulphuric Acid 0-7%	B	C	D	A	B		A	B	A		B
Sulphuric Acid 20%	D	C	D	A	D		B	D	A		C
Sulphuric Acid 50%	D	C	D	D	D		C	D	B		D
Sulphuric Acid 100%	D	C	B	D	A		D	D	B		D
Sulphurous Acid	B	D	D	D	B		C	D		B	A
Tannic Acid	A	A	A	A	A	B	B	A		B	A
Tartaric Acid	A	D	D	A	A	D	A	A		A	B
Tetraethyl Lead	B	B	C		B						
Toluene	A	A	A	A	A	D	D	A		A	A
Tomato Juice	A	C	C		A		A				
Transformer Oil	A	B	A		A		B				
Tributyl Phosphate	A	A	A	A	A		C				
Trichloroethylene	A	C	A	A	B	D	D	A		B	A
Turpentine	B	A	A	A	A		D	A		A	A
Urea	B	B	C	B	B			B			
Varnish	A	A	C		A		A				
Vegetable Oil	A	D	B	B	A		B	A			
Vinegar	C	D	D	A	A	B	D			A	A
Water, Boiler Feed	C	C	B	A	A						
Water, Fresh	A	A	C		A		A				
Water, Salt	C	C	D	A	B	B					
Whiskey	C	C	D	C	A	B	A				
Wine	C	B	D	C	A	B	A				
Xylene-Dry	A	A	B	A	B		D				
Zinc Chloride	D	D	D	B	D	B	A	B		A	A
Zinc Sulfate	C	D	D	B	B	B	A	B		B	A

H. BONDING OF LADDER TRAY

Bonding must be done at intervals not exceeding 15 m (49'). There are a number of ways to achieve the above:

- maintaining electrical continuity at all joints by using ladder tray as a bonding conductor.
- running sufficiently sized conductor in the tray system. This conductor must be bonded to the tray at the above mentioned intervals.
- attaching a bonding wire to the tray which is connected to the grounding points (e.g. to the grounded support system).

DEFINITIONS & ABBREVIATIONS

SECTION PROPERTIES		
Symbol	**Unit of Measure**	**Definition**
A	cm2 (in2)	*Cross-sectional area*
I	cm4 (in4)	*Moment of inertia*
N	angle degrees (0)	*Angle of unspecified magnitude*
r	mm (in)	*Radius of gyration*
S	cm3 (in3)	*Section modulus*
WEIGHTS, LOADS & FORCES		
Symbol	**Unit of Measure**	**Definition**
C	kg (lbs)	*Compressive force or load*
c	kg/in.m (lbs/in.ft)	*Tray cover weight (uniform load)*
F	kg (lbs)	*Axial force or load (tension or compression indefinite)*
fs	psi	*Fiber stress (may be tension or compression, but not shear)*
M	mm-kg (in-lbs)	*Bending movement*
P	kg (lbs)	*Total individual tray-span load imposed on a tray support*
PO	kg (lbs)	*Pullout (tension) load on fasteners*
Q	kg (lbs)	*Total individual tray load for a span*
SR	kg (lbs)	*Slip resistance of a Gloss Strut lock nut/bolt or other type fastener developing a frictional resistance to sliding*
T	kg (lbs)	*Tensile force or load*
t	kg/in.m (lbs/in.ft)	*Tray weight (uniform load)*
V	kg (lbs)	*Shearing force or load*
W	kg/in.m (lbs/in.ft)	*Uniform load of cable, tray and cover combined*
w	kg/in.m (lbs/in.ft)	*Cable weight (uniform load)*
COMPONENT DIMENSIONAL RELATIONSHIPS		
Symbol	**Unit of Measure**	**Definition**
a	mm (in)	*Partial length of a member*
b	mm (in)	*Partial length of a member*
e	mm (in)	*Eccentric distance (from a longitudinal axis) of a load applied to a structural member*
K		*Represents a value (factor) based on column support conditions which mathematically describes the end conditions of the column*
L	mm (in)	*Unbraced length of column strut or brace*
l	mm (in)	*Single unspliced length of cable tray or other component*
s	mm (in)	*Span between supports*
x	mm (in)	*Bending moment arm for a vertical force*
y	mm (in)	*Bending moment arm for a horizontal force*

SUPPORT STRUCTURE INTRODUCTION

This section is to be used as an aid in the design of economical support systems for ladder tray. Support methods and suggestions are to be used only as general guidelines for dealing with standard design problems and are not to replace the engineering involved for specific projects.

The information relates only to structural design and the choice of support structure. For specific structural data please refer to the strut manufacturer's data. For data on ladder tray please refer to proceeding data located in this section.

NOTES:

1. Space does not allow for all the infinite possibilities to accommodate special site conditions, however we have attempted to show as many examples as possible. We have listed support details for general types of support structures commonly used for typical conditions.

2. There are three (3) main types of support structures illustrated: (1) suspension, (2) brackets, and (3) direct bearing. There are variations of (1) and (2).

3. Suspension methods shown with strut as structural elements must use strut with a minimal wall thickness of .105". Those suspension methods shown with all-thread rods may substitute strut.

4. Strut bracket supports as well as bracket fittings as shown in the following drawings are suggestive components. Calculations for capacity and suitability for specific design load will ultimately determine the components to be used.

5. Solid bottom tray is used in the majority of the illustrations. The use of ladder and ventilated tray is noted.

DESIGN INFORMATION

A. DESIGN PARAMETERS

1. Solid strut is used for all calculations and analysis.

2. Support structures for ladder tray are attached only to the primary structural elements of the structure and in some cases to secondary elements eg.) columns, girders, beams, roof trusses, and bar joists. For the last two elements, unless otherwise specified by a structural engineer, attachments are made to the panel points. The ladder tray designer is responsible for obtaining authorization from a structural engineer for the adequacy of these structural elements. Structural elements not to be used are piping and conduit, mechanical equipment, catwalks, sub girts and purlins, bridging, wall studs (metal and wood), ceiling and floor panels.

3. Component selection used in the supporting structure is to be based on the allowable load (w) for the ladder tray being used as well as the weight of the ladder tray (t) and covers (c).

4. The total design load is comprised of: a) static loads of ladder tray discussed in the following support methods b) allowance for live loads experienced during construction and (c) allowance for live loads from anticipated future expansions. For outdoor installations the total design load must also include: d) allowances for additional live loads such as snow and ice and e) lateral loads such as wind. To determine these outdoor allowances the designer should consult local building codes as well as referencing past construction.

5. Span loads are conservatively estimated to be 50% at each end support and 125% at each intermediate support for multiple span continuous ladder trays, uniformly loaded, with equal spans and loads, at a consistent elevation and running in a straight line.

6. i. If the ratio of a ladder tray width to support span is greater than 2/3 then ventilated and solid bottom trays are assumed to be uniform loads across the width of the ladder tray upon their supports.
ii. If the ratio of tray width to support span is less than 2/3 than point (concentrated) loads are assumed.
iii. Each siderail of ladder tray is assumed to be a point (concentrated) load on the support. The optimum ratio is 1.0.

7. Diagonal bar bracing (excludes strut bracing) are not considered as supporting any load or to be lateral. They resist transverse racking only.

8. i. If the strut manufacturer's data does not contain numbers for **Allowable Axial Tensile Load (T)** but instead has data classified as **Maximum Column Load applied at C.G.** (concentric), one may use the latter as a substitute for (T).

If none of the above is available, and the only data available from the strut manufacturer is the areas (A) of the strut-section then use the following formula to determine the **Allowable Axial Tensile Load (T)**
T = (fs)(A) where fs (allowable fibre stress) = 24,000 psi

ii. If the strut manufacturer's data does not contain numbers for the **Allowable Bending Moment (M)**, but instead has data pertaining to the **section modulus (S)** about the x - x (1-1) axis of the strut-section then (M) can be calculated via the following formula: **M = (fs)(s) where fs = 24,000 psi**

9. **Columns** are structural elements that meet the following criteria:
i. are loaded parallel to the length
ii. transfers a load from a higher level
iii. may be vertical and
iv. classified as any element that is subjected to compression loads e.g. diagonal or knee brace. **Buckling** is the failure of a column visible by its loss of straightness.

Allowable column load is dependent on:
i. type of loading
ii. the length of the column element – column length is measured from brace point to brace point (where column is restrained from lateral movement in all directions)
iii. material and cross sectional shape and
iv. the conditions of support

There are two types of column loading:
i. **concentric (axially)** – loads applied to the center of gravity of a column's cross section and
ii. **eccentric** – loads applied any distance from the column's center of gravity.

Depending on the support conditions an appropriate value is selected which mathematically describes the end conditions of the column with respect to the maximum column load applied at the columns center of gravity. There are four (4) main support condition combinations.

i. Fixed Top – Fixed Bottom
Top and bottom of the column is restrained vs. lateral and rotation movement (factor .65).

ii. Fixed Bottom – Fixed/Free Top
Bottom is restrained vs. lateral and rotation movement while top is restrained against rotation movement only (factor 1.2).

iii. Pinned Top – Fixed Bottom
Top is allowed to rotate but is restrained against lateral movement while the bottom is restrained against rotation and lateral movement (factor .80).

iv. Pinned Bottom – Pinned Top
Both ends are allowed to rotate but are restrained against lateral movement. The valve of a columns radius of Gyration (r) is determined by its cross sectional shape. Normally a column with a longer (r) makes for a better column than one with a smaller (r). There are different (r's) for each axis of a column. The columns final design is normally determined by the axis with the smallest (r).

10. The load carrying capacity of all-thread hot rolled steel rods should be determined by confirmation with ASTM A575 and A576.

B. DESIGN REQUIREMENTS

1. Uniform tray loads must be as balanced and evenly distributed as possible by:
i. distributing cables across the entire tray width and
ii. positioning the same number of trays on bracketed supports on opposite sides of symmetrically suspended systems at the same elevation, while limiting this out-of-balance difference to 15%.

2. Do not use strut spring nuts on all-thread suspension rod systems. Instead use a 1-5/8" x 1-5/8" square washer on the open side of the strut channel and a flat round washer on the closed side of the channel member. As a locking unit use either square or hex head nuts above and below the strut member.

3. Clamping mechanisms such as CGA-* and ECG/ECZ-* must be used to securely anchor the ladder tray to it's support mechanism.

4. Racking must be prevented by the adequate use of both lateral and longitudinal bracing. This stability can be provided by the intersections of ladder tray either in a perpendicular or vertical direction.

5. Careful provisions must be made with respect to vertical tray runs to ensure that they are sufficiently braced and anchored at the top and bottom. These two points will carry the entire load of this tray run. To shorten the length of the brace, the designer should look for the nearest structural elements as listed above in item ii. under Design Parameters.

6. Illustrated lateral bracing is one of the two (2) types:
i. flexible bracing (braided steel wires) on both sides and
ii. a rigid brace (strut) on one (1) side of the support.

Both systems can be interchanged. For outdoor applications lateral bracing must be designed for additional external loads eg. wind.

7. Strut support elements must have lateral bracing to prevent lateral buckling at intervals not exceeding 2.1 m (7'-0"). If the open side of the strut element is in compression, the two lips of the strut must be joined at intermediate intervals not exceeding 1.1 m (3-1/2"), as well as at or near the beam ends. This can be achieved by the use of a 90º strut fitting clamped to the strut using spring lock nut(s) and 1/2" hardware.

8. Galvanic corrosion of dissimilar metals e.g. between aluminum ladder tray and ungalvanized steel, should be accomplished through the separation of these two elements by the use of an insulator such as high density polyurethane plastic, tape, mastic or a chemical isolator produced by Penatrox or Nolux.

9. For strut used as bracing supports the maximum slenderness ratios (L/R) are:
- i. 200 when loaded in compression and
- ii. 240 when loaded in tension

10. When vertically stacking ladder trays always maintain adequate clearance above each tray run to allow for the installation of the cable and start with the narrowest (lightest) tray on top and work downwards with the widest (heaviest) tray on the bottom. As per the CEC Rule 12-2200 Subrule 6 the minimum clearances for ladder trays shall be:
- a. 150 mm (6") vertical clearance, excluding ladder tray depth, between ladder trays installed in tiers, except that where cables of 50 mm (2") diameter or greater may be installed, the clearance shall 300 mm (12");
- b. 300 mm (12") vertical clearance from the top of ladder tray to all ceilings, heating ducts and heating equipment and 150 mm (6") for short length obstructions;
- c. 600 mm (24") horizontal clearance on one side of ladder trays mounted adjacent to one another or to walls or other obstructions, where the width of the cable tray installation does not exceed 1 m; and
- d. 600 mm horizontal clearance on each side of cable trays mounted adjacent to one another, where the width of the cable tray installation exceeds 1 m.

11. When sizing concrete inserts consult the manufacturer's technical data. As a rule of thumb when sizing concrete inserts for tensile loads exerted less than 305 mm (12") apart single point loading must be considered.

C. DESIGN PROCEDURES

1. The achievement of an economical support system consistent with adequate structural performance is the ultimate design goal. The designer must consider the material vs. labour equation. He must not underestimate the high cost of field labour needed to achieve a materially economical design. Even though the ultimate material cost may be somewhat higher in a most economical installed system it often times results in the simplest system.

2. Diminishing economies never justify the compromising of safety. One must:
- i. comply with all applicable safety and building codes
- ii. consider all possible loads that the structure will undergo during installation and
- iii. anticipate all loads that the structure will be exposed to during it's entire life span

3. Approximate ladder tray location within the structure must be selected based upon:
- location of the structural framing system that is available for support
- freedom from interfering with the function of the structure
- freedom from interference with other systems e.g. mechanical and HVAC
- economy

A balance must be achieved between the cost of trays and the support structure. If spans are too short, supports are too frequent and the resultant cost is too high. Conversely if spans are too long, the tray cost is too high. The optimum span, which varies according to the tray type, the type of support method and labour rates (field vs. shop) can be determined by doing estimates of cost installed for a few trial spans.

4. For the types of attachments to be used on the supporting structure for the various support methods please reference the following chart:

SUGGESTED ATTACHMENT TO STRUCTURE

STRUCTURE MATERIAL	WITH PROVISION IN STRUCTURE FOR LADDER TRAY SUPPORT	WITHOUT PROVISION IN STRUCTURE FOR LADDER TRAY SUPPORT
Structural Steel	Beam clamps bolting or welding	Beam clamps bolting or welding
Brick or Concrete Block	Anchor Bolts	Masonry Expansion Anchors*
Precast Concrete	Special inserts for bolting or welding	Masonry Expansion Anchors*
Poured-in-place Concrete	Continuous or Spot Inserts Anchor Bolts*	Masonry Expansion Anchors*

** Minimum spacing manufacturer's recommendations, otherwise 3 diameters.*

5. Determine ladder tray types and sizes, rung spacing, covers if required, the span and support locations and types. If possible avoid the use of unsymmetrically (eccentrically) loaded supports. Where possible use METHODS #1,2,3,5 and 12; especially for heavy loads.

6. At each location select the most suitable support method from the drawings and determine the loads on each component based upon anticipated loading conditions. Start with the actual tray load and work successively through each supporting component.

7. Determine the loads imposed on the building structure by the complete ladder tray system and obtain assurance from appropriate engineers that the structure will sustain it.

8. Standardization on component parts and sizes will minimize the types and quantities required. This will achieve the greatest simplicity and economy in sizing strut and designing methods.

D. DETAILED DESIGN PROCEDURES

Before starting one should familiarize themselves with the following various support system schematics that follow:

PROCEDURE 1

i. Do a layout on paper of the various support locations and ladder tray runs.
ii. As per "DESIGN REQUIREMENTS" balance loads in grouped tray runs.
iii. Calculate the anticipated cable load (w).
iv. As per "DESIGN PROCEDURES" regarding optimum span lengths determine the spans.
v. Based on the required span and load (w) select the appropriate size and type of ladder tray. Load (w) must include future loads and any covers at the required safety factor.

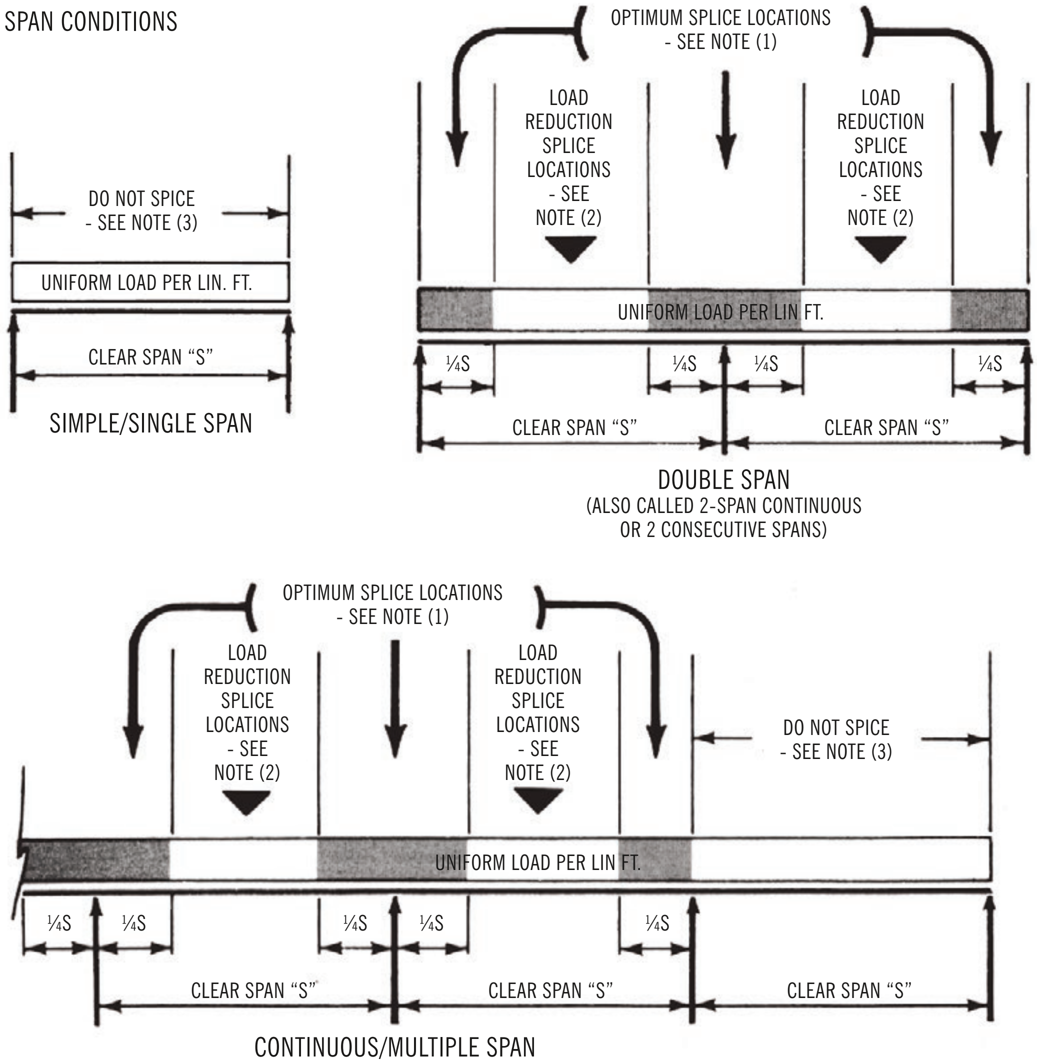
PROCEDURE 2

i. At each support location select the best support design and determine the tray loads. If splice connectors occur between supports, refer to the following chart to calculate tray load reduction.

APPROXIMATE LOAD REDUCTION FACTORS FOR SPLICE CONNECTORS IN THE MIDSPAN RANGE					
Tray Type	Siderail Height	Universal Connector	Single Span	Double Span	Multiple Span*
Ladder	All	UC*-**	Do Not Splice	.87	1.00
Ventilated	All	UC*-**		.80	1.00
Solid	All	UC*-**		1.00	1.00

– ABOVE FACTORS ARE FOR STRAIGHT LENGTHS ONLY
– LADDER TRAY FITTINGS REQUIRE ADDITIONAL SUPPORTS
* NOT FOR THE ENDS OF SPANS

SPAN TYPES



NOTE (1)

- Universal connectors located at splices have less load capacity than continuous tray sections. Connectors that are located at minimal stress points take full advantage of ladder tray strength.
- Ideal connector locations are at 1⁄4 the clear span distance from the support.
- The next best connector locations are between the above points and the tray support.
- Allowable loads listed for each tray in the following sections can be used without reduction.

NOTE (2)

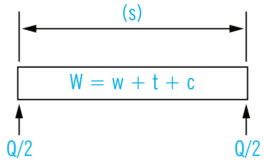
- For connector locations at or near mid-span, the allowable loads for ladder tray must be reduced.
- The amount of reduction is dependent on the types of span and the model of tray.
- The reduced allowable load is calculated by multiplying the normal allowable load for each tray section by the appropriate load reduction factors from the above chart.

NOTE (3)

- Avoid splices in simple/single spans and at the end spans of continuous/multiple spans.

ii. w = w + t + c
Q = W(s) where Q= total span load

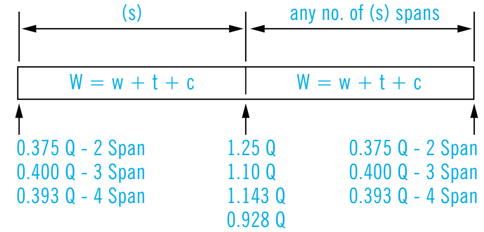
iii. Distribute the total tray run load to the supports:
a. End Supports - P = .50Q - Simple/Single span (for each end if a simple/single span tray run)



SIMPLE/SINGLE SPAN

b. Intermediate supports for double or continuous/multiple span tray runs

P = 1.25Q - 2 Span
1.10Q - 3 Span
1.143Q - 4 Span (for 1st interior support)
0.928Q - 4 Span (for middle support)



DOUBLE OR CONTINUOUS/MULTIPLE SPANS

iv. For each specific Support System follow the respective DESIGN PROCEDURE.

v. Once all the procedures for all the tray supports have been complete, follow Procedure 8 and 9 for the entire tray system.

PROCEDURE 3
For each support location design the support and bracing system. The first component that must be sized is the support beam. The ladder tray must be centered on the support element.

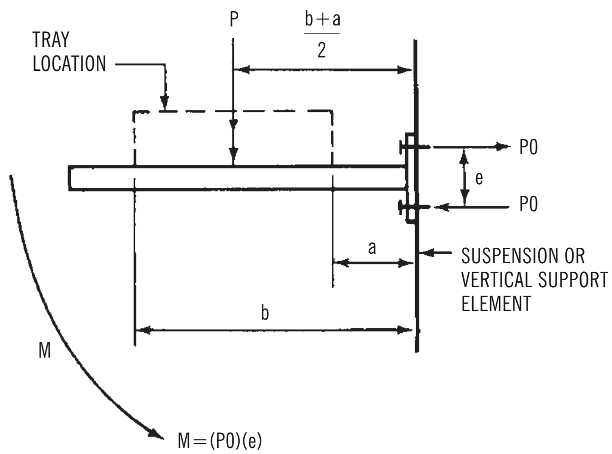
a. Suspension or Direct – Bearing Tray Supports

Ladder, Ventilated and Solid Tray
i. Size support beam with tray load (P) as a uniform load. Consult strut manufacturer's data to select member that has the closest allowable uniform load for the required span.
ii. If the span of the support channel is more than 1.5 times the tray width, than assume the tray load is concentrated. Size the support strut with reference to the manufacturer's data.

b. Bracket Tray Supports

Ventilated and Solid Tray
i. To minimize the bending moment (M) position the tray as close to the bracket support as possible.
ii. The maximum length of most off-the-shelf bracket supports is 600 mm (24"). That limits the width of the tray to 450 mm (18"). If adequate lead times exist, longer brackets can be ordered from some of the strut distributors.
iii. Calculate the bending moment (M) for bracket supports used for Ventilated and Solid Tray.

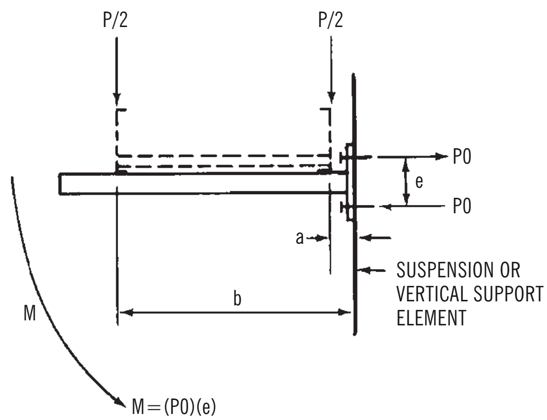
$$M = \frac{P(a+b)}{2} \qquad M = (PO)e$$



Ladder Tray

iv. The load for ladder tray is applied as two (2) concentrated loads. To determine the bending moment (M):

$$M = \frac{P(a+b)}{2} \qquad M = (PO)e$$

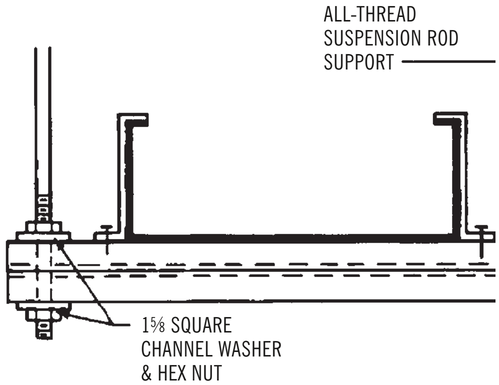


v. After determining the bending moments in iii. and iv. select a bracket type from the manufacturer's data that has both moment and uniform load capacities suitable for (M) and (P).

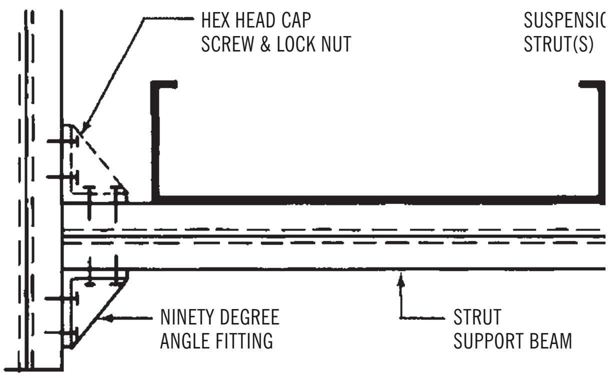
PROCEDURE 4

There are three (3) typical connections used on all support methods. One must verify the load transfer from the support member to the suspension support for each one.

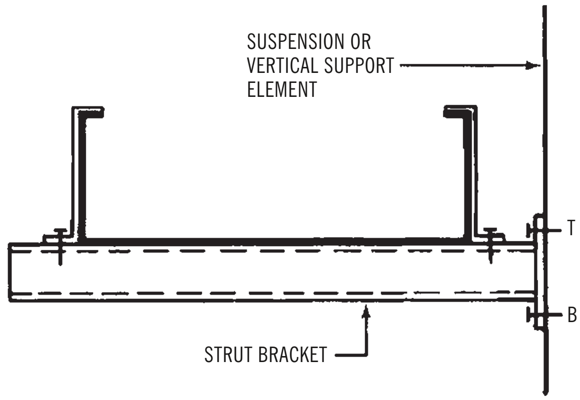
a.
- Assuming that the tray is centered, the support beam load (P) is equally distributed to each all-thread suspension rod as a tensile load P/2.
- Tray clamps, either CGA-* or ECZ-*/ECG-* must be used to fasten the tray to the support beam.



b. • The tray's support beam load is transferred through the slip resistance of the lock nuts on the 90º corner fitting connecting the support beam to the suspension strut.
• Use one (1) or two (2) pairs of corner fittings as required. To support the total load (P).
• If one pair, the slip resistance of the lock nut must be greater than P/4. If two pairs, the S/R must be P/8.



c. • Siderail clamps carry no load.
• The bolt on top of the support bracket must be checked for pull out (PO).
• The lock nuts used on the bracket attachment must be adequate to transfer the tray load (P) as well as the bending moment (M) to the vertical support.
• The slip resistance of both the top (T) and bottom (B) bolts must be checked for suitability to sustain the load (P).



PROCEDURE 5

a. SUSPENSION STRUTS
- The illustrations in this article show the use of back to back strut for framing suspension channels. One may use single strut.
- The use of single vs. back to back may depend on the pull out strength/slip resistance of the top attachment locking nut.
- The strut selected must be compatible with the supporting bracket.

b. ALL-THREAD SUSPENSION RODS
- As outlined in Procedure 4, add up the individual support reactions for each rod from all the tray tiers.
- The cumulative load of all the tray tiers must be used to size the all-thread rods.
- The suspension rod must have sufficient tensile capacity.
- The diameter of the rod must not be less than 12 mm (1/2") and be compatible with the attachment fittings.

i. **Strut Loaded Axially**
- As per the load computations in Procedure 5b. size the strut suspension member in the same manner.
- Select from the strut manufacturer's data a size of strut that has adequate tensile strength.
- With reference to the manufacturer's data (allowable loads for strut/lock nuts and spring nuts) check for adequacy regarding the **pull-out (PO)** strength and **slip resistance** in the top attachment bolts.
- If insufficient, recalculate the size of the strut and re-check tensile strength.

ii. **Strut Loaded Eccentrically (Unsymmetrically)**
- This condition exists when the **tray load (P)** is applied any **distance (e)** from the neutral axis of the strut.
- This imposes a bending **moment (M)**, equal to **(Pe)** on the strut.
- Total all the tray axial loads and bending moments imposed on the strut(s).

$Tsum = P_1 + P_2 + P_3$
$Msum = Tsum + esum$
$Msum = T_1e_2 + T_2e_2 + T_3e_3$ M = bending moment due to eccentric loading

- The total of tensile fiber stress must not exceed 24,000 psi. Determine the total **fiber stress (fs)** from both tensile and axial loads.

$$fs = \frac{T\ Total}{A} + \frac{M\ Total}{S}$$

TOTAL FIBER STRESS = AXIAL FIBER STRESS + BENDING FIBER STRESS

- If **fs** is less than 24,000 the selected strut is adequate.
- When using back to back strut the open side of the strut that is opposite trays is in compression if T/A is less than M/S.
- If compression exists, then see DESIGN REQUIREMENTS #7 to prevent these open lips of the strut from buckling.

PROCEDURE 6
See the ATTACHMENT SUGGESTION chart under DESIGN PROCEDURES #4 and follow the various steps as listed for each of the following.

i. BEAM CLAMPS
- For the clamp selected, check the manufacturer's data to ensure that it's allowable load capacity exceeds the tensile load imposed by the suspension member.
- Verify the structural integrity of the supporting beam.

ii. EXPANSION ANCHORS (MASONRY) AND CONCRETE INSERTS
There are two (2) sets of calculations to be done for concrete anchors based on **tensile** and **shear** loads.

a. Using the tensile loads that act on strut suspension or threaded rod member(s):
   - Check for the adequacy of the **pull-out** capacity of the inserts and anchors referencing the manufacturer's data.
   - Use sufficient quantities of anchors to support the load (a minimum of 2)
   - Check the strength adequacy of the supporting structure.

b. If a **shear** load on the connection is imposed as a result of the mounting method of the strut suspension element (eg. strut bolted to the side of a supporting beam);
   - The anchors must be checked for allowable shear load rather than pull out (PO).
   - Check out the strength adequacy of the supporting structure.

c. Check the **slip-resistance** of the lock nuts supporting the strut suspension member(s).
   - Assuming that 90º Corner Angle Fittings are normally used in pairs and only **axial** loading exists, then each of the four (4) lock nuts support 1⁄4 of the **tensile** load from the suspension strut.
   - Consult the manufacturer's data (load charts) to ensure that the locking nut's **slip-resistance** capacity is greater than 1⁄4 of the imposed tensile load.

d. Check out the strength adequacy of the supporting structure.

iii. 90º CORNER ANGLE FITTING
- When strut suspension elements are eccentrically loaded a 4 HOLE WEBBED 90º FITTING is probably the best choice to ensure a tight rigid connection.
- When purely axial loads are being transmitted a lighter gauge version of the above fitting can be used.
- 12 mm (1/2") or larger diameter bolts must be used regardless of the fitting used.

One must do two (2) distinct verifications:

a. Check the **pull-out strength** of the anchors as outlined in PROCEDURE 6(ii). For concrete inserts:
   - Assume the total tensile load's distributed over 3 rather than 4 bolts for the pair of corner fittings.
   - Assume 100% load for the first hole in each fitting, and 50% for the second (total of 1.5 bolts).
   - Both **slip-resistance** and **pull-out** loads will be higher than the above calculations if the bending moments are transmitted through the 90º corner angle connections.
   - The anchors, with reference to the manufacturer's data, must be checked for allowable shear load.

b. Check out the strength adequacy of the supporting structure.

iv. SIDE MOUNTED EXPANSION ANCHORS (MASONRY)
See the ATTACHMENT SUGGESTION chart under DESIGN PROCEDURES #4. SYSTEM DIAGRAMS #4 and #5 illustrate concrete as a supporting beam (structural steel can be substituted as well). There is a two (2) step system for sizing expansion anchors.

a. For supporting the total tray load **(P)** under **axial** conditions one must select anchors for adequate **shear** values.
   - Consult the anchor manufacturer's data for allowable shear using 100% as allowable shear strength.
   - If data is given as **ultimate** divide by the desired safety factor (use 2.0) to obtain the allowable **shear** strength.
   - The **tensile** loads (T) in the suspension strut must be less than the total amount of the shear strengths for the anchors to be used.

b. If an **eccentric** tray load creates a bending moment in the suspension struts, one must check the **pull-out** (PO) of the top anchor.
   - See SYSTEM DIAGRAM #4 and #5. Determine the bending moment in the suspension struts.

$M = P_1e_1 + P_2e_2 - P_3e_3 - P_4e_4$

Determine PO:

M = PO (y) y = distance between centers of the groups of anchors bolts.

   - The **pull-out** value of the anchor(s) must be greater than (PO).
     – If (M) is positive, the top anchor(s) are in tension (PO).
     – If (M) is negative, the bottom anchor(s) are in tension.
     – If (M) is zero, the tray load is in a balanced condition.
   - Group as many required anchors to develop the required distance to (PO).
   - (PO) can be reduced by placing the anchor groupings as far apart as possible.
   - Pay attention to the minimum distance between the anchors and from the edges.
   - A web stiffener between the beam's flanges may be needed if attachment is made to a steel beam.
   - Check the supporting beam for crucial **torsional** loading.

c. If back to back strut is used:
   i. the anchors are in a **shear** condition one strut depth away from the beam, and
   ii. are **compressing** the sides of the strut.

d. Use only 12 gauge strut to minimize:
   i. the bending of the expansion anchor and
   ii. the potential buckling of the sides of the strut. If the capacity is adequate it is preferable to use single strut as a suspension member. Step 2 can be avoided. To avoid step b. and to eliminate eccentrically, one may balance the tray loads symmetrically about the support struts [SYSTEM DIAGRAM 5(b)].

PROCEDURE 7

- Design the lateral bracing for ladder tray supports as required. They should be spaced at either:
  i. A maximum of 11.0 m (36'-0") apart or ii. spaced every length for 3 m (10'-0") length of ladder tray.
- For exterior installations see DESIGN REQUIREMENTS #6.
- For additional loads requiring bracing see DESIGN PARAMETERS iii) and iv).
- Use either a. or b. methods assuming that the bracing carries no load.

a. LATERAL BRACING USING GUY WIRES
   - Guy wires (stranded is preferred to solid) must have a minimum allowable tensile strength of 227 kg (500 lbs) with a safety factor of 2.
   - Guy wires must be installed symmetrically in pairs (one on either side of the support).
   - These wires provide bracing in tension only.

b. LATERAL BRACING USING RIGID STRUT
- Three assumptions are used for strut selection:
  - i. Maximum deflection of 25 mm (1") @ 91 kg (200 lbs).
  - ii. Minimum allowable uniform beam load of 91 kg (200 lbs).
  - iii. Maximum slenderness ratio (L/r) of 200.
- Using the length of the brace (L) between connections as the span, select a strut size meeting assumption i. and ii. from the manufacturer's beam load charts.
- With reference to the strut manufacturer's physical and strength data, find the **radius of gyration** (r) for both x-x and y-y axes.
  - – Divide the smaller of the two (r) into the brace length (L).
  - – If resultant L/r is under 200, strut size is adequate.
  - – If L/r is over 200, try using a heavier strut or:
  - – Work backwards by determining the minimum (r) (divide length of the strut brace by 200).
  - – Select a strut in which the lower of it's two (2) (r) values is just above the minimum.
  - – With reference to the manufacturer's beam load charts, check it for allowable load and deflection.

c. FLAT BAR BRACES – DIAGONAL
- No design or checking of the load rating for this brace is required.
- Use for applications as shown in drawings that appear in this section.

d. LATERAL BRACE STRUTS USING RIGID STRUT
- Lateral brace struts are only used with supports that are **eccentrically** loaded. Examples appear in DESIGN DIAGRAMS #6, 13, 14 and OPTIONS (e) and (f).
- Depending on the design they can be used in either **compression** or **tension**.
- Size the strut by calculating either the compressive load or axial tensile load that is transferred to the brace.
- If in **compression**, consult the manufacturer's column load charts using the brace length between connections in mm (inches) as unbraced column height.
- From the **Allowable Axial Load Columns**, select the strut(s) having the lowest allowable axial load that is sufficient for the computed strut length.
- If in **tension**, consult the manufacturer's **Allowable Tensile Loads**.
- As described above in (b) along with #9 in DESIGN REQUIREMENTS check the slenderness ratio **(L/r)**.

PROCEDURE 8
- The longitudinal bracing is the next item to be designed.
- Demands vary with: i. the flexibility of the tray supports and ii. the length of the run.
- Use the same design procedures as listed in PROCEDURE 7(a) and (b) above.

Refer also to #4 in DESIGN REQUIREMENTS for bracing and vertical run suggestions.

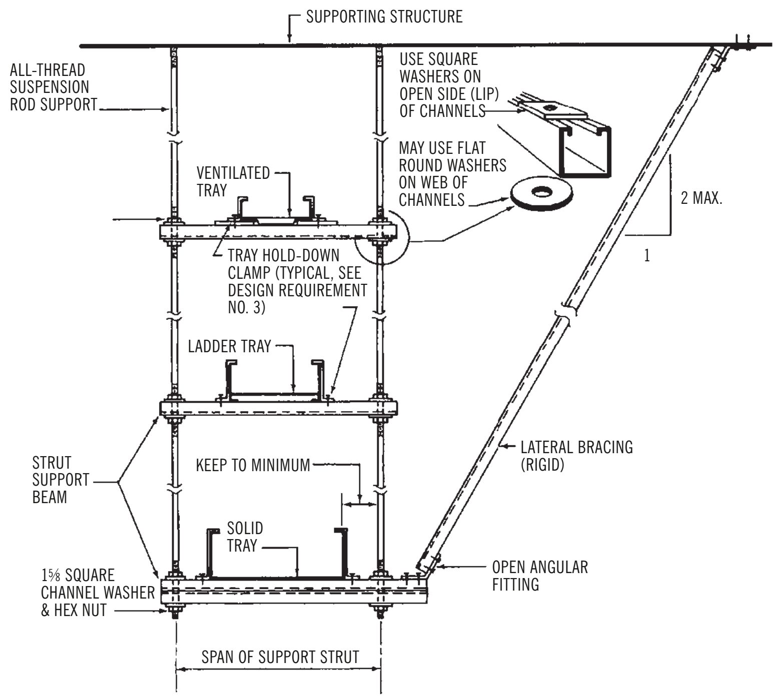
PROCEDURE 9
Once all bracing layouts and support locations have been designed:
- Start from the beginning and recheck the complete job.
- Verify all the assumptions made during the design.
- Ensure all the DESIGN REQUIREMENTS are met.
- Direct your attention to the following items:
  - – Ease of installation.
  - – Total overall economy of both field labour and material.
  - – Safety factors covering pending installation plus any future (anticipated) installs.
  - – Field working conditions.
  - – Standardization of component parts, simplicity and compatibility with attachment components.
  - – Coordination with other subtrades vis a vis scheduling and layout.

SUPPORT SYSTEMS

A. (i) SUSPENSION SUPPORTS USING ALL-THREAD ROD

SYSTEM #1

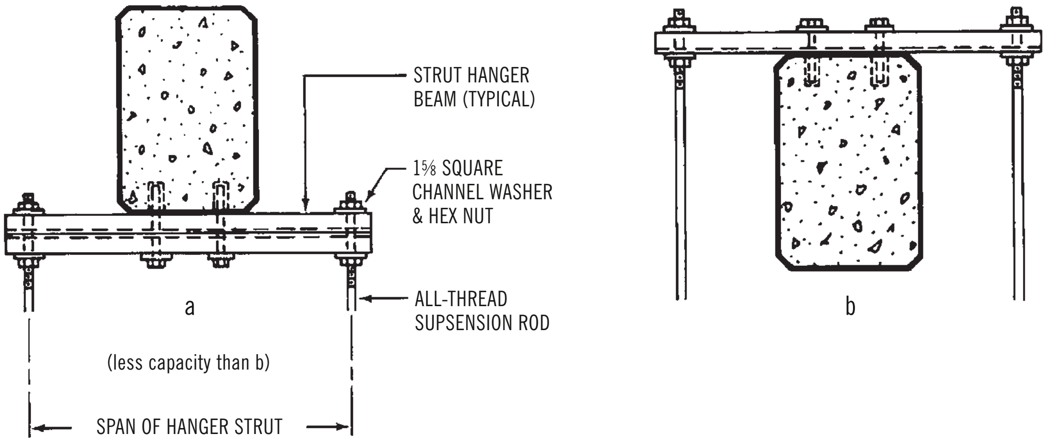
- In order follow PROCEDURES 3 through 6.
- For attachment as shown in the following drawing use PROCEDURE 6(iii).
- Dependant upon conditions any of the ALTERNATE ATTACHMENT METHODS (a) (b) (c) (d) (e) and (f) can be used.
- Lateral bracing is designed using PROCEDURE 7(a) or 7(b).



ALTERNATE ATTACHMENT METHODS

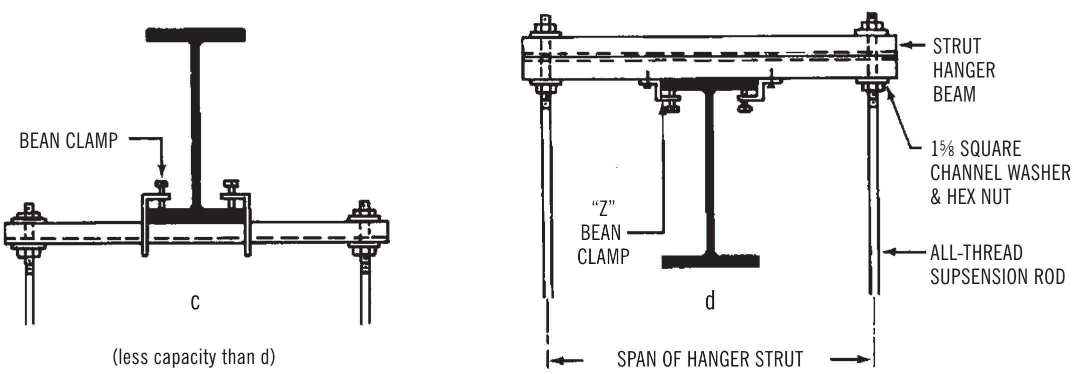
METHODS (a) (b)

- To calculate the size of the required strut hangar beam, go back to PROCEDURE 3(a) using the **tensile** loads that were calculated in PROCEDURE 5(a) for the suspension rods done for SYSTEM #1.
- Visualize the system as being inverted (the concrete beam is a **concentrated** load) and calculate the size of the hanger beam (strut) for a **uniform** load twice that of the concrete beam load.
- This calculation is equal to the total load transferred to both the suspension rods.
- From the manufacturer's beam load charts select the strut size using the distance between the rods as the span.
- For ALTERNATE METHOD (a) check the anchorage using PROCEDURE 6(a) and both suspension rod loads as total pull-out (PO) load for the anchors.
- The anchor for ALTERNATE METHOD (b) may be undersized since the load is supported by the beam.
- METHOD (b) is preferable to (a).
- If (a) must be used, maintain the required minimum spacing distance between the anchors and be conservative when sizing these anchors.



METHODS (c) and (d)

- As in (a) and (b) above size the components and select the appropriate beam clamps from the manufacturer's catalogue for the calculated allowable load.
- If the suspension rods in (d) are equally loaded the beam clamps do not have to be sized for load as they are simply securing the hangar strut.
- If the beam is not centered refer to ALTERNATE METHOD (f).



METHODS (e) and (f)

- These two (2) methods create a noticeable amount of torsion on the supporting structural element.
- They should be avoided, especially if the structural element is relatively light.
- Method (f) which in essence is method (d) above is preferable.
- When 'a' and 'b' are equal the strut brace is not required.
- As per PROCEDURE 5(a) above for Method 1 which calculates the tensile load ($P/_2$) use ($P/_2$) and proceed with the following steps:

METHOD (e)

- A bending moment **(M)** and an **axial compression force (C)** are imposed on the hangar strut.
- There are two forces **(M)** and **(C)** that resist the **tension (T)** in the strut.

BENDING MOMENT $$(M) = \frac{P[(a)(b)]}{2(a+b)}$$

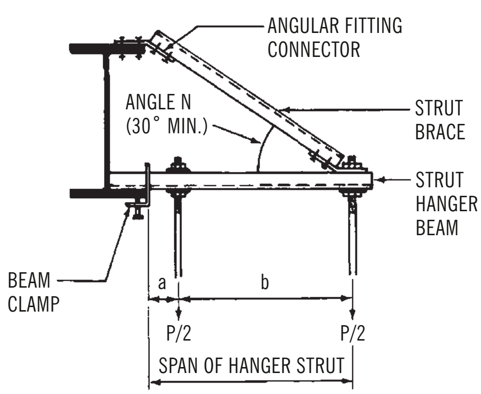
AXIAL FORCE $$(C) = \frac{P(a+b/2)}{(a+b)\tan N}$$ **N minimum 30º**

- Using (M) and (C) as well as the section area (A) and section modulus (S) [(A) and (S) derived from the strut manufacturer's data], use trial and error to size the hangar strut.
- As per PROCEDURE 5(b) (for unsymmetrically loaded strut) substitute (C) for (T) so that the total **compressive stress** reaches but does not exceed 24,000 psi.
- For the strut brace compute it's **axial tension** by:

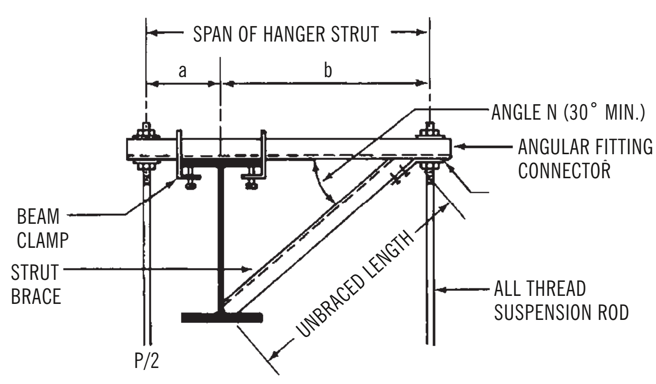
$$T = \frac{P(a+b/_2)}{(a+b)\sin N}$$ **N minimum 30º**

- From the above calculation for (T) select a strut channel of adequate capacity from the manufacturer's allowable tensile load charts.
- As per PROCEDURE 7(b) check the slenderness ratio (L/r) for both the tension strut brace and the strut hangar beam.
  - The tension strut brace must be sized to a maximum (L/r) of 240.
  - The strut hangar beam must be sized to a maximum (L/r) of 200.
- To attach the tension strut brace select an appropriate 4-hole (do use 2-hole) angular fitting connector(s).
  - Use locking nuts with a slip-resistance greater than T/2.
  - At end of the strut brace, the locking nuts must be sized for (T).
- At the connection point for the tension strut brace to the top flange of the supporting beam, size the connecting bolts per:

V bolts = [T(cos N)] Verify the allowable shear loads for the bolts.



e

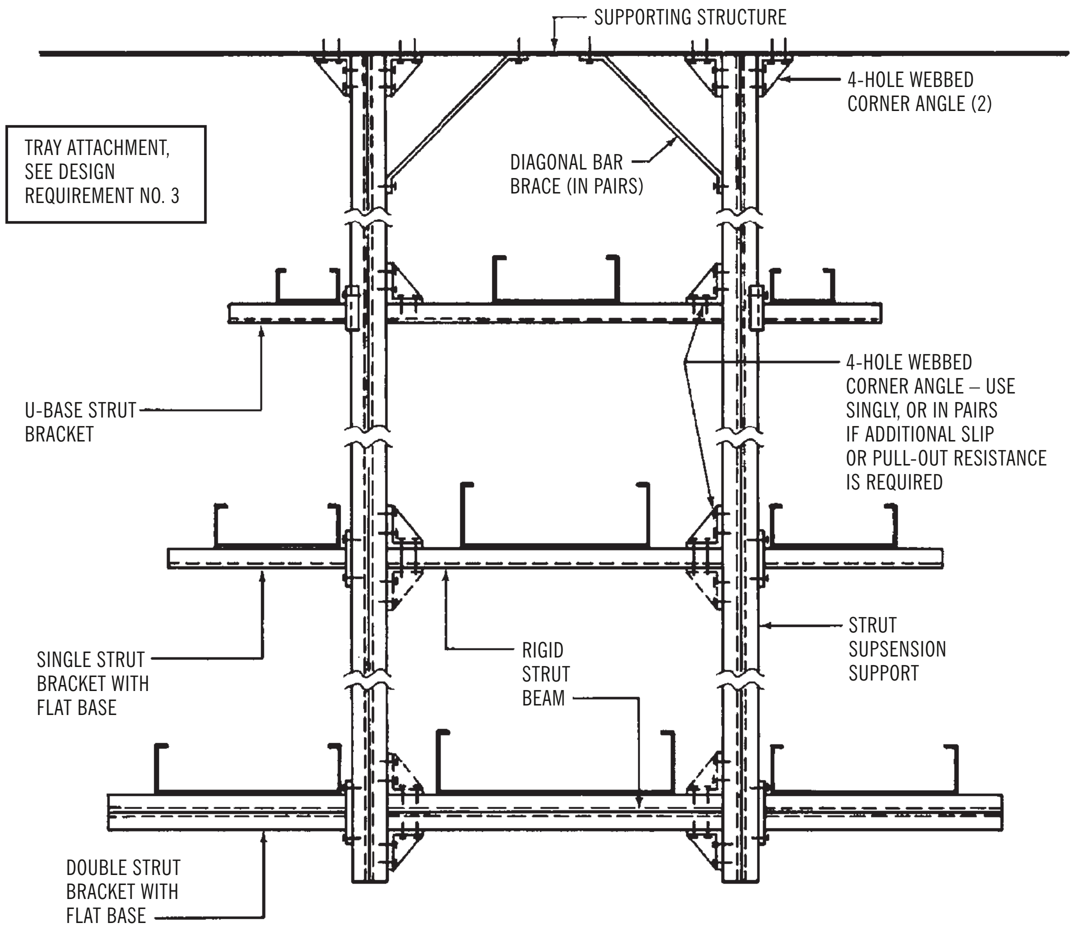


f

A. (ii) SUSPENSION SYSTEMS USING STRUT

DESIGN #2

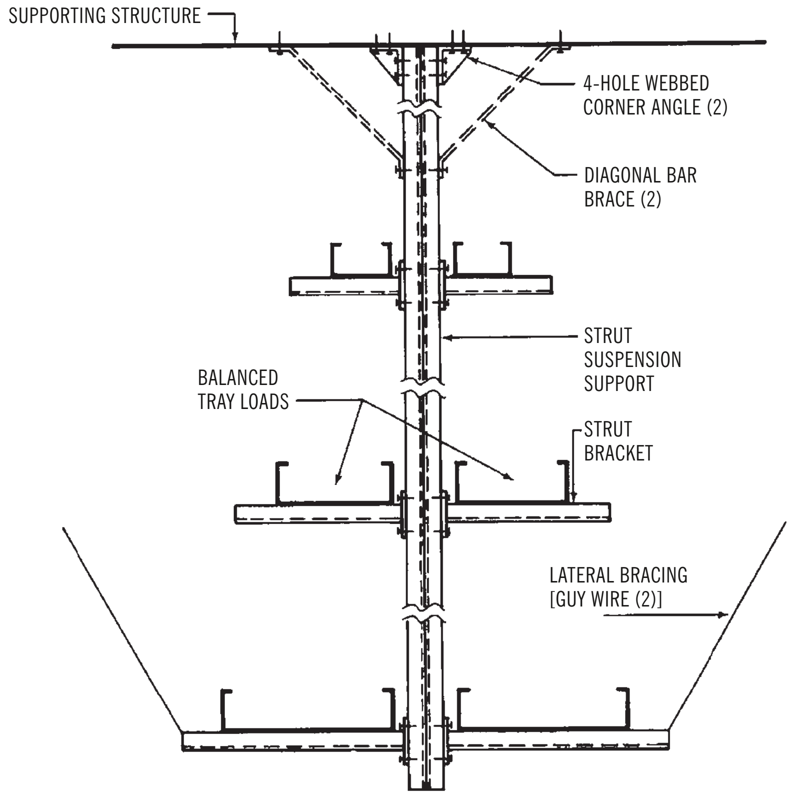
- For all center trays follow PROCEDURE 3(b).
- For all outside trays follow PROCEDURE 4(c).
- For all axially loaded strut follow PROCEDURE 5(a).
- Then follow PROCEDURES 6(iii) and 7(c).
- Any of the Alternate Attachment Methods (a,b,c,d,e and f) may be substituted for PROCEDURE 6(iii), providing that strut suspension is kept.



DESIGN #3

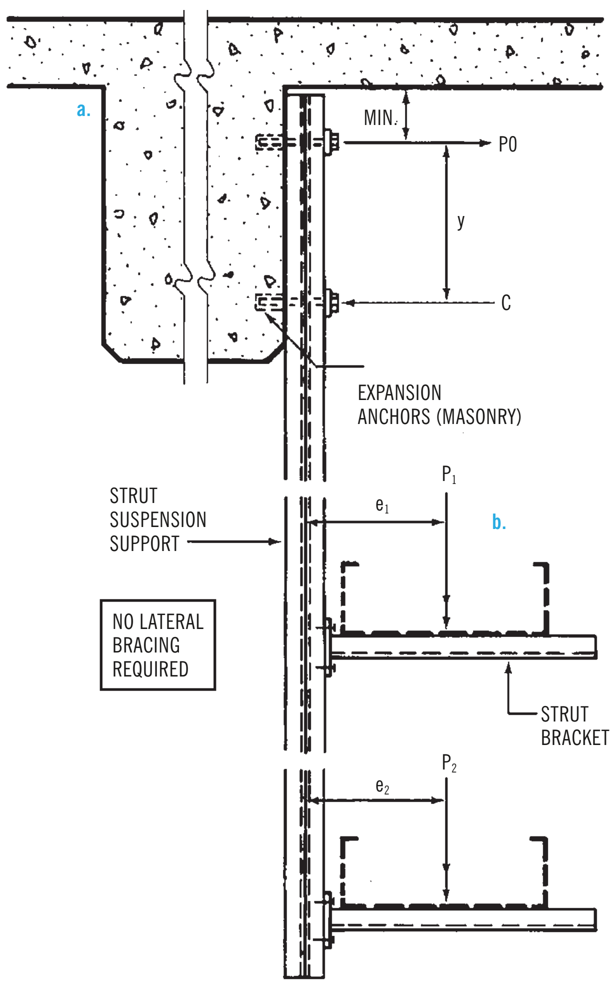
- One should attempt to balance the tray loads on either side of the suspension element as much as possible.
- For axially loaded strut proceed with the following steps:

  – PROCEDURE 3(b)
  – PROCEDURE 4(c)
  – PROCEDURE 5(a)
  – PROCEDURE 6(iii)
  – PROCEDURE 6(ii)
  – Either PROCEDURE 7(a) or 7(b)
  – PROCEDURE 7(d)



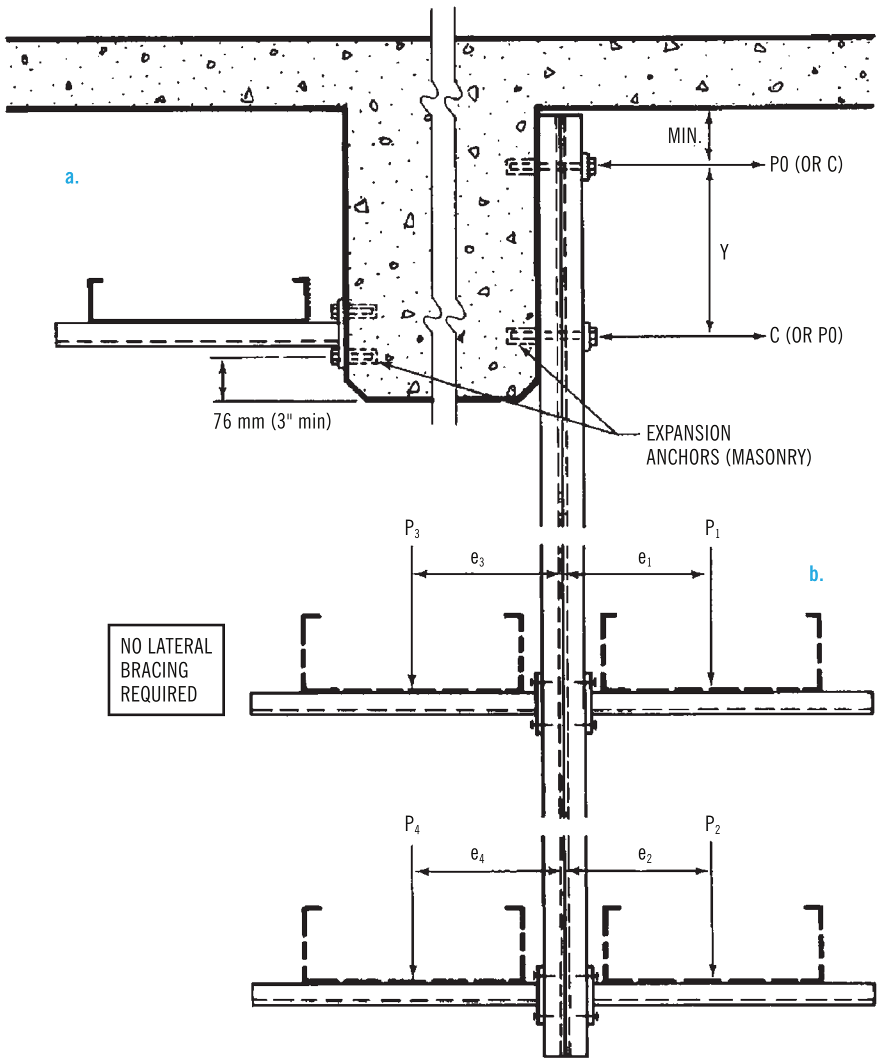
DESIGN #4

- For eccentrically loaded strut proceed with the following steps:
  - PROCEDURE 3(b)
  - PROCEDURE 4(c)
  - PROCEDURE 5(a)
  - PROCEDURE 6(iv)
  - OMIT PROCEDURE 7 since this system is a rigid moment transmitting connection that requires no lateral bracing.



DESIGN #5

- For Design 5(b) balance the tray loads on either side of the suspension strut as much as possible and then proceed with the following steps:
  - PROCEDURE 3(b)
  - PROCEDURE 4(c)
  - PROCEDURE 5(a)
  - PROCEDURE 6(iv)
  - OMIT PROCEDURE 7 since there is no requirement for lateral bracing
- For Design 5(a) the procedures are the same as for 5(b) above except for the exclusion of PROCEDURE 5(a).



DESIGN #6

- This design is a combination of two (2) possibilities.
- Both designs contain the following assumptions:
  - As illustrated all trays are attached to the same side of the suspension strut.
  - All tray loads are approximately equal.
  - All connections are bolted versus welding.
  - If tray loads are not equal then they are tiered according to size; smallest at top to largest at the bottom.
  - The vertical spacing of brackets is fairly equal.
  - The attachment point for the angled compression strut brace is either at or below the attachment point of the lowest tray bracket (horizontal).

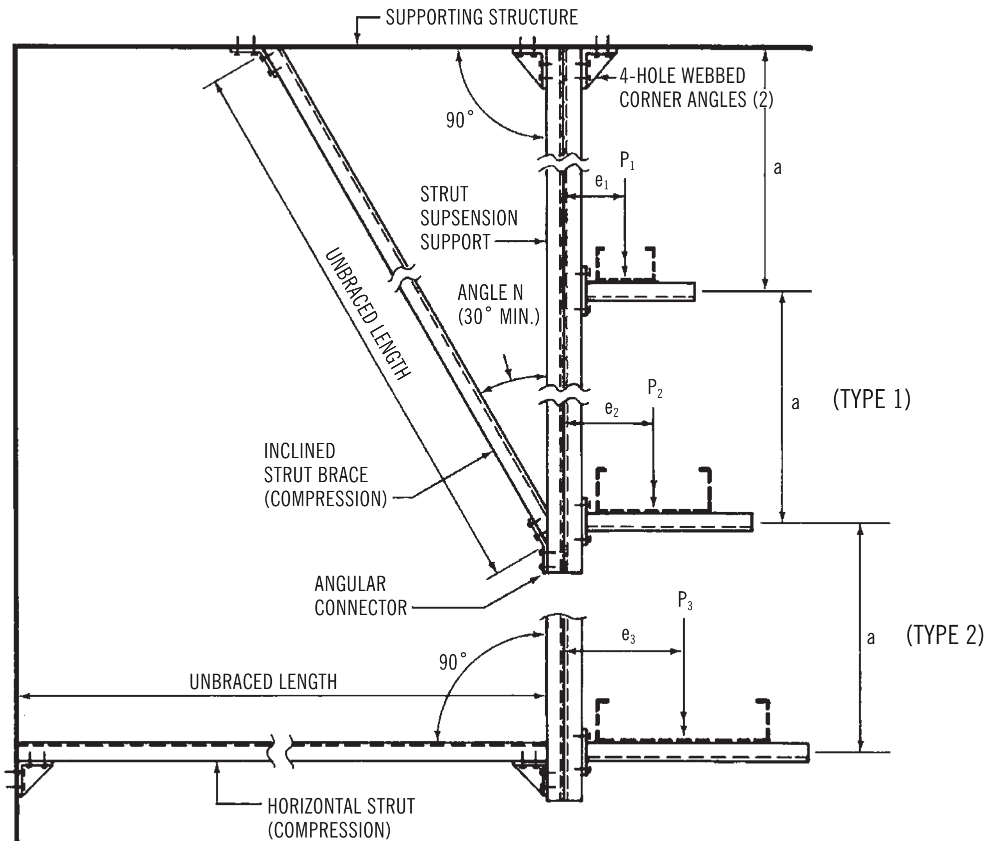
- For TYPE 1 follow PROCEDURES 3(b) and 4(c) to select the correct bracket tray supports.
  - Suspension struts must be sized for their combined **fiber** (stress) from **axial** tensile load and the larger of the following two (2) bending moments:

$$M_1 = P_1e_1 + P_2e_2 \quad \text{or} \quad M_1 = P_2e_2$$

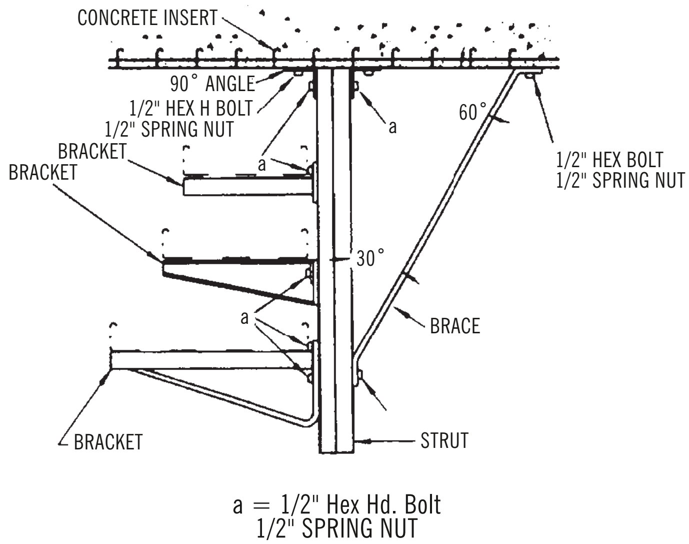
- Combined fiber stress (fs) = M/S + T/A
  **For strut that is loaded eccentrically see Procedure 5(a).*

$$fs = \frac{M_1}{S} + \frac{P_1 + P_2 + \frac{P_1e_1 + P_2e_2}{2a(\tan N)}}{A} \quad \text{and} \quad fs = \frac{M_2}{S} + \frac{P_2 + \frac{P_1e_1 + P_2e_2}{2a(\tan N)}}{A}$$

- If both (fs)'s are under 24,000 psi, then the strut is adequate.

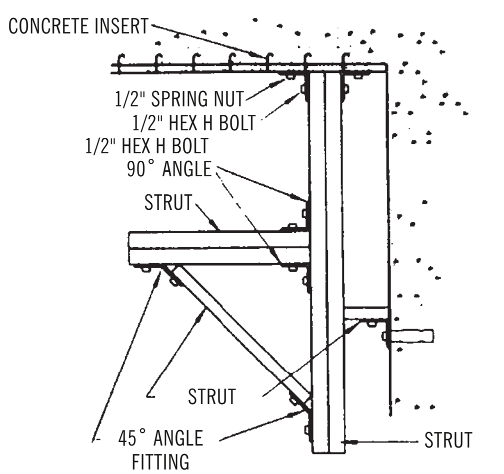


EXAMPLE 1:



Suspended column, carrying brackets, braced to the ceiling.

EXAMPLE 2:



Suspended column, holding bracket and console to wall.

- The 90º Corner Angle Fittings located at the top of the suspension strut must be sized:
  - Use the tensile load (T) of the suspension strut where:

$$\mathbf{T = \frac{P_1 + P_2 + P_1e_2 + P_2e_2}{2a(tanN)}}$$ and follow:

  - PROCEDURE 6(iii) to calculate the slip resistance for the bottom bolts and the shear and pull-out capacities for the top bolts (all bolts are for the 90º Angle Fitting).
  - Their total shear capacities must be greater than the shear load (V) where:

$$\mathbf{V = \frac{P_1e_2 + P_2e_2}{2a}}$$

- The braced compression strut must then be sized.
  - Determine the **axial** compression load (C) where:

$$C = \frac{P_1e_1 + P_2e_2}{2a(\sin N)}$$

  - From the strut manufacturer's data for **Allowable Axial Load** [eccentric load of 680 kg (500 lbs)] select a strut size that has an allowable load greater than (C).
  - Using PROCEDURE 7(d) check the **slenderness ratio** (L/r) for a maximum of 200.
  - Use PROCEDURE 6(iii) to size the bolts at each end of the braced compression strut for slip **resistance** (S/R) equal to (C).
  - The connection point between the suspension strut and the braced compression strut must have sufficient **slip resistance** (S/R) capacity exceeding:

$$S/R = \frac{P_1e_1 + P_2e_2}{2a(\tan N)}$$

  - At the connection point for the braced compression strut to the support structure, the bolts must have total shear capacity to carry the same shear load (V) as in the above 90^o Corner Angle Fittings.
  - The bolt shear capacity must be twice (2x) as great since there are only two (2) bolts.

TYPE 2

- As in TYPE 1 above the only differences lay in the load values. Replace in order the following formulas for those listed in TYPE 1.

$$M_1 = \frac{P_1e_2 + P_2e_2 + P_3e_3}{3} \quad \text{or} \quad M_2 = 2/3\,(P_2e_2 + P_3e_3) - \frac{P_1e_1}{3} \quad \text{or} \quad M_3 = P_3e_3$$

Using these 3 formulas, find **fs**:

$$fs = \frac{M_1}{S} + \frac{P_1 + P_2 + P_3}{A} \quad \text{and} \quad fs = \frac{M_2}{S} + \frac{P_2 + P_3}{3} \quad \text{and} \quad fs = \frac{M_3}{S} + \frac{P_3}{A}$$

None of these (fs)'s to exceed 24,000 psi.

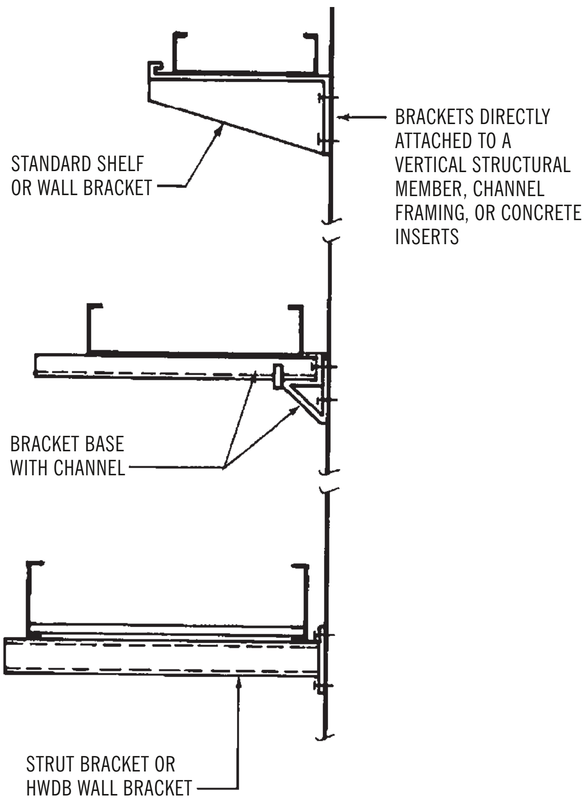
$$T = P_1 + P_2 + P_3 \qquad V = \frac{P_1e_2 + P_2e_2 + P_3e_3}{3a} \qquad C = \frac{P_1e_1 + P_2e_2 + P_3e_3}{3a}$$

  - The bolts used at either end of the horizontal strut brace may be of any size, since the strut carries no load (in compression state).
  - Use the deepest element available for the horizontal strut. It should be sized for the possibility of a vertical load.
  - As in TYPE 1 check for its adequacy to carry a load.

B. SUPPORTS USING BRACKETS

DESIGN #7

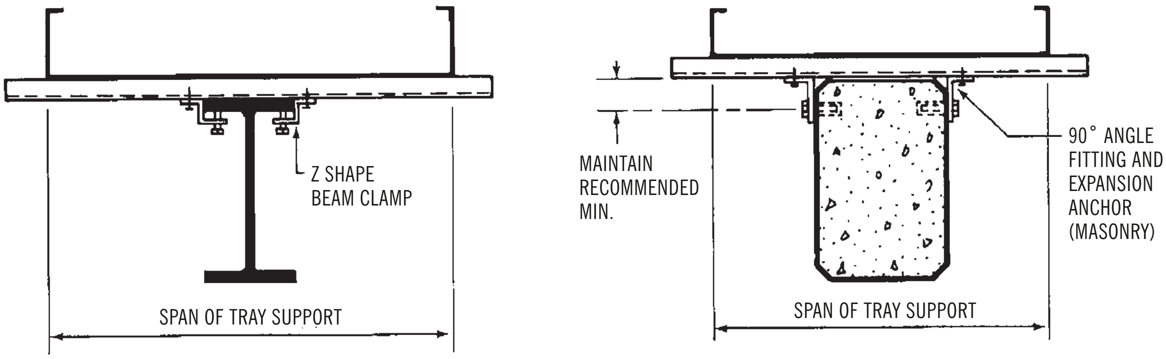
- Select one of the three bracketed support styles illustrated below based on:
  - Required attachment method (see Attachment Suggestions under DESIGN PROCEDURES 4).
  - Load compatibility.
- Follow PROCEDURES 3(b) and 4(b).
- Check the strength adequacy of the supporting structure.



C. DIRECT – BEARING SUPPORTS

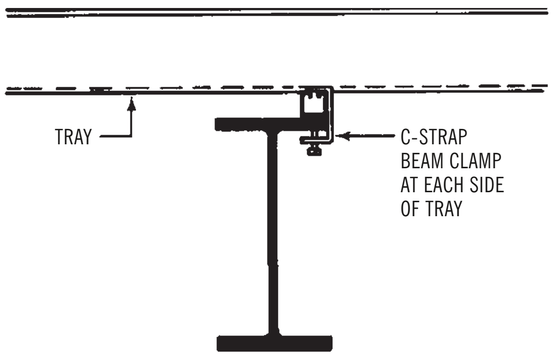
DESIGN #8 AND DESIGN #9

- Anchorage needs no sizing as it carries no load. Alternate Attachment Method (d) is similar to these two (2) designs. Both designs contain the following assumptions:
  - The beam (inverted) imposes a concentrated load on the tray support unless the beam flange is greater than 2/3 of the tray width in which case:
  - Consider (P) as a uniform load.
  - Between the supports the tray carries the entire cable load (P).
- As per PROCEDURE 3(b) size the support strut using the width of the tray as the span and load (P).
- Check the strength adequacy of the supporting beam.



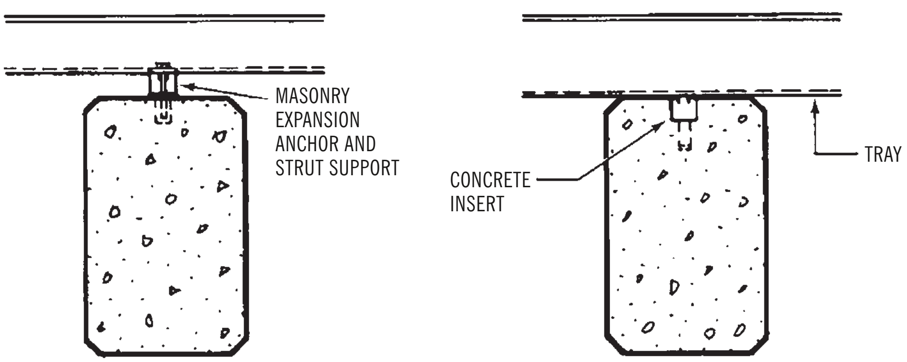
DESIGN #10

- Anchorage needs no sizing as it carries no load.
- Use strut with a minimal wall thickness of 12 gauge to prevent possible side wall buckling under conditions of heavy tray loading.
- If the tray load is heavy check the supporting beam, especially if it has either a thin or wide flange.



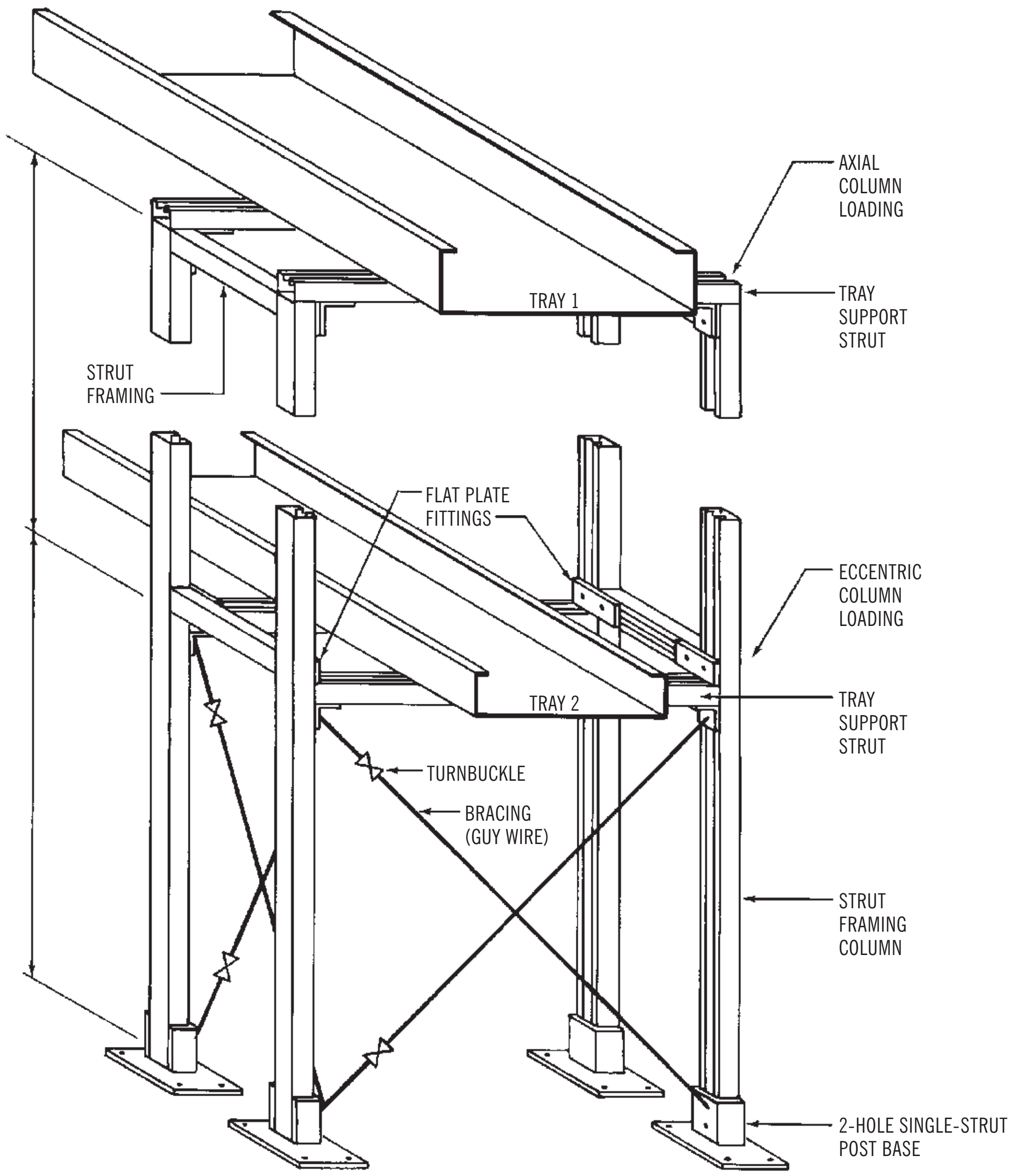
DESIGN #11

- This design is similar to DESIGN #10. Please reference manufacturer's data regarding concrete inserts.



DESIGN #12

- This design consists of free-standing double support framing strengthened by both lateral and longitudinal framing.
- One frame may be used as temporary framing, but must be prevented from overturning by the use of longitudinal bracing.
- Each of the two (2) transverse frames (permanent structure) carries 1⁄2 of each tray load (P).
- Supports should be spaced so that (P) of tray 2 (should be lighter than tray 1) is not greater than 2712 kg (6000 lbs).
- PROCEDURES 2, 3(a) and 4(a) are to be followed for the upper support strut.
- Each segment of the top column carries:
  - P/4 of TRAY 1 axially.
- Each segment of the bottom column carries:
  - P/4 of TRAY 1 axially.
  - P/4 of TRAY 2 eccentrically.
- From the strut manufacturer's column load charts size each strut column segment individually using each segment's unbraced column height.
- For the top segment select a strut section that is adequate for P/4 of TRAY 1 from the **Maximum Column Load Values Applied at C.G.**
- For the bottom segment select a strut section that is adequate for P/4 of TRAY 1 from the column for **Maximum Allowable Load at Slot Face.**
- The choice for the entire column is the heavier of the two struts.
- Verify the slenderness ration (L/r) for maximum of 200 and follow PROCEDURE 7(a) or 7(b).
- PROCEDURE 8 can be omitted as the unit is braced longitudinally.



DESIGN #13

- The support beam must be sized for combined fiber stress from axial compression (C) and bending moment (M):

$$M = Pb \qquad C = \frac{P(a+b)}{a(\tan N)} \qquad fs = \frac{M}{S} + \frac{C}{A} \qquad fs = \frac{Pb}{S} + \frac{P(a+b)}{a(\tan N)A}$$

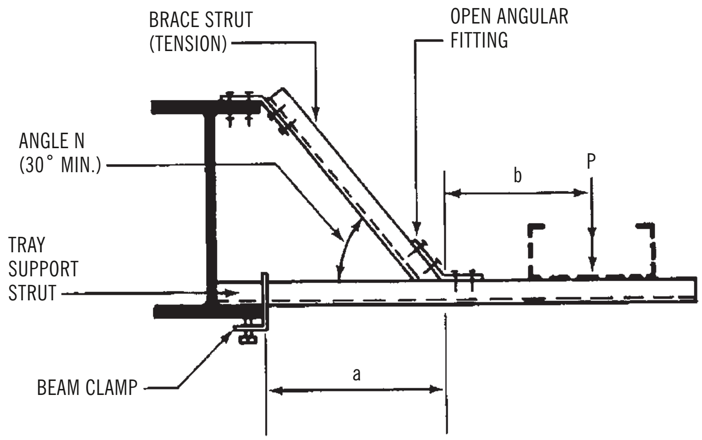
- From the strut manufacturer's data choose the appropriate section. As a result of the above calculations verify that **(fs)** is less than 10,867 kg (24,000lbs). Reference PROCEDURE 5(a) for eccentrically loaded struts where:

$$T = \frac{P(a+b)}{a(\sin N)}$$

Select a strut section from the manufacturer's data with adequate load capacity to carry the **tensile** strut load(T).

- Verify the slenderness ratio (L/r) for maximum of 240.
- To resist uplift created by the tray support strut, the beam clamp's allowable load capacity should exceed (Pb/a).
- Follow PROCEDURE 6(iii) to verify that the tension strut lock nut bolts' slip resistance capacity is greater than (T).

- From the strut manufacturer's data check the lock nut bolts connecting to the tray support strut for:
  - Minimum slip resistance of (T)(cos N).
  - Pull-out (PO) equal to P(a+b)/a as described in PROCEDURE 6(iii).
- The total of the shear values for the bolts connecting to the support beam must equal the minimum of T(cos N).



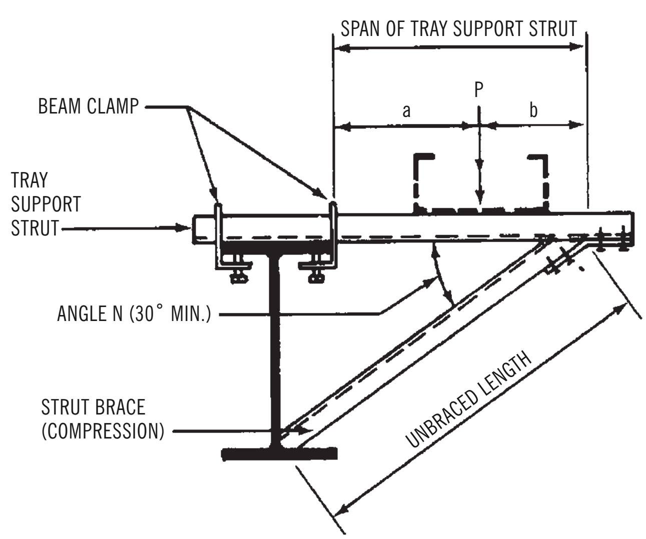
DESIGN #14

- This design is similar to DESIGN #13. Tension and compression have been reversed in both the strut brace and the tray support strut.
- For the tray support strut substitute the following formulas:

$$M = \frac{Pab}{(a+b)} \qquad fs = M/S + T/A$$

Where: $T = \dfrac{Pa}{(a+b)(\tan N)}$ $\qquad fs = \dfrac{Pab}{(a+b)s} + \dfrac{Pa}{(a+b)(\tan N)A}$ $\qquad$ **Using (C) where:** $C = \dfrac{Pa}{(a+b)(\sin N)}$

- Select the compression strut from the strut manufacturer's data on Maximum Column Load Applied at C.G.
- Instead of a maximum of 240 in DESIGN #3, verify that the selected strut section's slenderness ratio (L/r) does not exceed 200.
- The total slip-resistance capacity of:
  - The two beam clamps and
  - The locking nut connections to the tray support strut must: exceed (T).
- The lower end of the strut brace must be connected to the structural support.



HOW TO DETERMINE THE SIZE OF A LADDER TRAY

The Canadian Electrical Code (CEC) was written for the verification of: 1. the ampacities of conductors in ladder trays and 2. the cable fill in ladder trays, however, little has been done to convert this into a procedure for determining the width of ladder tray.

*This guide will make reference to the **CEC,** Part I, 23rd Edition, Section 12, **Rule 2210**.*

Example 1 is Subrule (1)
Example 2 is Subrule (2)
Example 3 is Subrule (3)
Example 3 is Subrule (4)
Example 4 is Subrule (5)

The following Teck 90 single and multi-conductor cables shall be installed in a ladder tray. Cable dimensions are subject to manufacturing tolerances and design changes. Unitray has referenced the Nual Conductors from Alcan Cable.

Type (A) 4 – 250 kcmil Aluminum single conductor cables as a feeder conductor for power panelboard “PX” – Cable Diameter 35.5 mm

Type (B) 1 – #4 AWG Copper four conductor multi-cable as a feeder conductor for emergency power panelboard “EPX” – Cable Diameter 37.4 mm

Type (C) 1 – #6 AWG Copper four conductor multi-cable as a feeder conductor for night light panelboard “NIX”– Cable Diameter 33.6 mm

Unitray has established a simple method of determining the right size of ladder tray to support any given amount of cable.

The following steps illustrate the **Unitray** simplified method for determining tray widths based on tray design and system voltage.

Step 1: Determine the cables diameter and the minimum required air space between single and multi conductors.

Step 2: Produce a drawing to visually display the cable layout to maintain the required air space between cables.

Step 3: Determine the minimum width of ladder tray using the following numerical guide factors:
1. diameter of each conductor
2. quantity of each conductor and
3. from step 1 above the quantity of required minimum air spaces for each conductor.

Step 4: Determine the maximum allowable ampacity of the conductors using T**ables 1, 2, 3, 4, 5A, 5C and 5D from the CEC**.

Using the appropriate subsections in **Section 12 Rule 2210 of the CEC**, we will cover all four possible scenarios using the previously mentioned conductors.

EXAMPLE 1

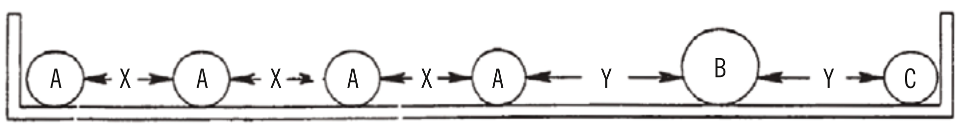
Subrule 1:
In ventilated and ladder-type trays, where the air space between adjacent conductors, or cables, or both is maintained at greater than 100% of the largest conductor or cable diameter, the ampacity of the conductors or cables shall be as follows:

a. Single-conductors, single-conductor metal sheathed or armoured cable and single-conductor mineral-insulated cable, as specified in **Tables 1 and 3**; and
b. Multi-conductor cables as specified in **Tables 2 and 4**, multiplied by the correction factor in **Table 5C** for the number of conductors in each cable.

Step 1: Determine the cable's diameter and minimum required air space between single conductors and multi conductor cables.

Minimum required air space between cables (in mm)
X Between A <> A = 35.5 mm x 1.01 = 35.855 mm
Y Between A <> B and B <> C = 37.4 mm x 1.01 = 37.774 mm

Step 2: Cable layout to maintain required air space between cables.



Step 3: Determine the minimum width of ladder tray.

(A) 35.5 mm	**x 4**	=	**142.000**
(B) 37.4 mm	**x 1**	=	**37.400**
(C) 33.6 mm	**x 1**	=	**33.600**
(X) 35.855 mm	**x 3**	=	**107.565**
(Y) 37.774 mm	**x 2**	=	**75.548**
Total width of ladder tray			**396.113 mm (396.113 x .0394 = 15.607 in)**

Step 4: Determine the maximum allowable ampacity of the conductors.

Cable(A) 250 kcmil **Table 3** Col.4 330 Ampere
Cable(B) #4AWG of 4 conductor cable **Table 2** Col.4 85 Ampere
Cable(C) #6AWG of 4 conductor cable **Table 2** Col.4 65 Ampere

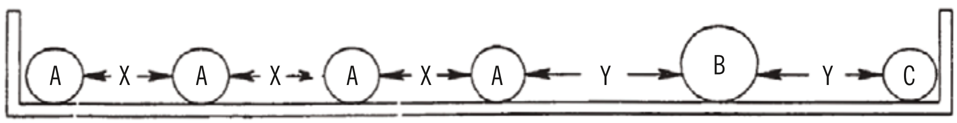
EXAMPLE 2

Subrule 2:
In ventilated and ladder-type cable trays, where the air space between adjacent conductors, cables, or both is maintained at not less than 25% nor more than 100% of the largest conductor or cable diameter, the ampacity of the conductors or cables shall be the value specified in Subrule (1), multiplied by the correction factor specified in **Table 5D** for the arrangement and number of conductors or cables involved unless a deviation has been allowed in accordance with **Rule 2-030** for other correction factors.

Step 1: Determine the cables' diameter and minimum required air space between single-conductors and multi-conductor cables. Minimum air space maintained between conductor, not less than 25% and not more than 100%.

X Between A <> A = 35.5 mm x .25 = 8.875 mm
Y Between A <> B and B <> C = 37.4 mm x .25 = 9.35 mm

Step 2: Cable layout to maintain minimum required air space between cables.



Step 3: Determine the minimum width of ladder tray.

(A) 35.5 mm	**x 4**	**=**	**142.000**
(B) 37.4 mm	**x 1**	**=**	**37.400**
(C) 33.6 mm	**x 1**	**=**	**33.600**
(X) 8.875 mm	**x 3**	**=**	**26.625**
(Y) 9.35 mm	**x 2**	**=**	**18.700**
Total width of ladder tray			**258.325 (258.325 x .0394 = 10.178 in)**

Step 4: Determine the maximum allowable ampacity of the conductors.

Cable (A) 250 kcmil 330A **(Table 3)** x.82 **(Table 5D)** = 270.6 Ampere
Cable (B) #4 AWG of 4 conductor cable 85A **(Table 2)** x .82 **(Table 5D)** = 69.7 Ampere
Cable (C) #6 AWG of 4 conductor cable 65A **(Table 2)** x.82 **(Table 5D)** = 53.3 Ampere

EXAMPLE 3

Subrule 3:
In ventilated and ladder-type trays, where the air space between conductors, cables, or both is less than 25%, and for any spacing in a non-ventilated ladder tray, the ampacity of the conductors or cables shall be the value as specified in **Table 2 or 4** multiplied by the correction factor specified in **Table 5C** for the total number of conductors in the ladder trays.

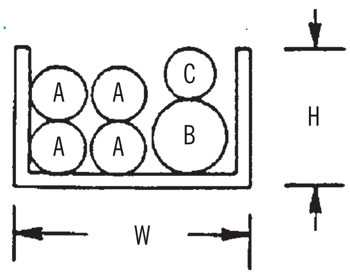
Subrule 4:
In determining the total number of conductors in the ladder tray in **Subrule (3), Rule 4-004(7) shall apply.** The correction factors specified in this Rule:

a. Apply only to, and shall be determined from, the number of power and lighting conductors in a cable or raceway; and
b. Shall not apply to conductors installed in auxiliary gutters.

Step 1: Determine the cables diameter and where air space between single conductors and multi-cable conductors for any spacing less than 25%. Minimum air space not required between the cables.

Step 2: Cable layout and determine the minimum width and height of ladder tray.

a.

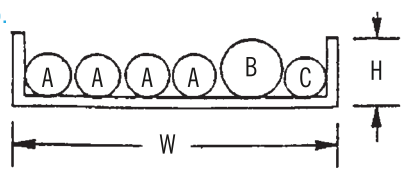


Width = (35.5 mm x 2) + 37.4 mm = 108.4 mm
= (108.4 x .0394 = 4.27 in)

Height = 38.6 mm + 37.4 mm = 71 mm
= (71 x .0394 = 2.7974 in)

Height = (35.5 mm x 2) = 71 mm
= (71 x .0394 = 2.7974 in)

b.



Width = (35.5 mm x 4) + 37.4 mm + 33.6 mm = 213 mm
= (213 x .0394 = 8.39 in)

Height = 37.4 mm = (37.4 x .0394 = 1.474 in)

Step 3: Determine the maximum allowable ampacity of the conductors.

Cable (A) 250 kcmil 215A **(Table 4)** x .7 **(Table 5C)** = 150.5 Ampere
Cable (B) #4 AWG of 4 conductor cable 85A **(Table 2)** x .7 **(Table 5C)** = 59.5 Ampere
Cable (C) #6 AWG of 4 conductor cable 65A (**Table 2)** x .7 **(Table 5C)** = 45.5 Ampere

How to determine the maximum allowable ampacity of the conductor where the ladder tray(s) are located in room temperatures above 30°C.

EXAMPLE 4

Subrule 5:
Where ladder trays are located in room temperatures above 30°C the temperature correction factor of **Table 5A** shall be applied to the ampacities determined from **Subrules (1), (2), and (3)** as applicable.

The Ambient Room Temperature 45°C. Therefore as indicated on **Table 5A** reference to Col. 1 and Col. 4, the correction factor = 0.85.

The maximum allowable ampacity of the conductors, for Example #1.
Cable (A) 250 kcmil 355A **(Table 3)** x 0.85 **(Table 5C)** = 301.75 Ampere
Cable (B) #4 AWG of 4 conductor cable 95A **(Table 2)** x 0.85 **(Table 5A)** = 80.75 Ampere
Cable (C) #6 AWG of 4 conductor cable 75A **(Table 2)** x 0.85 **(Table 5A)** = 63.75 Ampere

The maximum allowable **ampacity** of the conductors, for Example #2.

Cable (A) 250 kcmil 355A **(Table 3)** x 0.82 **(Table 5D)** x 0.85 **(Table 5A)** = 247.44 Ampere
Cable (B) #4 AWG of 4 conductor cable 95A **(Table 2)** x 0.82 **(Table 5D)** x 0.85 **(Table 5A)** = 66.22 Ampere
Cable (C) #6 AWG of 4 conductor cable 75A **(Table 2)** x 0.82 **(Table 5D)** x 0.85 **(Table 5A)** = 52.28 Ampere

The maximum allowable ampacity of the conductors, for Example #3.

Cable (A) 250 kcmil 230A **(Table 4)** x 0.70 **(Table 5C)** x 0.85 **(Table 5A)** = 136.85 Ampere
Cable (B) #4 AWG of 4 conductor cable 95A **(Table 2)** x 0.70 (Table 5C) x 0.85 **(Table 5A)** = 56.53Ampere
Cable (C) #6 AWG of 4 conductor cable 75A **(Table 2)** x 0.70 (Table 5C) x 0.85 **(Table 5A)** = 44.63 Ampere

4-004 AMPACITY OF WIRES AND CABLES (SEE APPENDIX B)

1. The maximum current which a copper conductor of a given size and insulation may carry shall be as follows:
   a) Single conductor, and single-conductor metal sheathed or armoured cable, in a free air run, as specified in **Table 1**;
   b) 1, 2, or 3 conductors in a run of raceway, or 2, or 3 conductor cable, as specified in Table 2; and
   c) 4 or more conductors in a run of raceway or cable, as specified in **Table 2** with the correction factors applied as specified in **Table 5C**;
   d) single-conductor and 2-, 3-, and 4-conductor cables and single-conductor and 2-, 3-, and 4-conductor metal-armoured and metal-sheathed cables, unshielded and rated not more than 5 kV, in conductor sizes No. 1/0 AWG and larger, installed in accordance with configurations described in Diagrams D8 to D11 in an underground run, directly buried or in a raceway, as specified in Tables D8A to D11B or as calculated by the IEEE 835 calculation method;
   e) underground configurations not specified in Item (d), in conductor sizes No. 1/0 AWG and larger, as calculated by the IEEE 835 calculation method;
   f) underground configurations in conductor sizes smaller than No. 1/0 AWG, as specified in Item (b) or as calculated by the IEEE 835 calculation method; and
   g) shielded cables rated 5 kV to 46 kV in sizes No. 2 AWG to 1000 kcmil, as specified in Tables D17A to D17N for the configurations described therein and the conditions described in Table D17, or as calculated by the IEEE 835 calculation method.

2. The maximum current that an aluminum conductor of a given size and insulation is permitted to carry shall be as follows:
   a) single-conductor and single-conductor metal-sheathed or armoured cable, in a free air run, with a cable spacing not less than 100% of the larger cable diameter, as specified in **Table 3**;
   b) one, two, or three conductors in a run of raceway, or 2- or 3-conductor cable, except as indicated in Subrule (2)(d), as specified in Table 4;
   c) four or more conductors in a run of raceway or cable, as specified in Table 4 with the correction factors applied as specified in Table 5C;
   d) single-conductor and 2-, 3-, and 4-conductor cables and single-conductor and 2-, 3-, and 4-conductor metal-armoured and metal-sheathed cables, unshielded and rated not more than 5 kV, in conductor sizes No. 1/0 AWG and larger, installed in accordance with configurations described in Diagrams D8 to D11 in an underground run, directly buried or in a raceway, as specified in Tables D8A to D11B or as calculated by the IEEE 835 calculation method;
   e) underground configurations not specified in Item (d), in conductor sizes No. 1/0 AWG and larger, as calculated by the IEEE 835 calculation method;

- f) underground configurations in conductor sizes smaller than No. 1/0 AWG, as specified in Item (b) or as calculated by the IEEE 835 calculation method; and
- g) shielded cables rated 5 kV to 46 kV in sizes No. 2 AWG to 1000 kcmil, as specified in Tables D17A to D17N for the configurations described therein and the conditions described in Table D17, or as calculated by the IEEE 835 calculation method.

3. A neutral conductor that carries only the unbalanced current from other conductors, as in the case of normally balanced circuits of three or more conductors, shall not be counted in determining ampacities as provided for in Subrules (1) and (2).

4. When a load is connected between a single-phase conductor and the neutral, or between each of two phase conductors and the neutral, of a three-phase, 4-wire system, the common conductor carries a current comparable to that in the phase conductors and shall be counted in determining the ampacities as provided for in Subrules (1) and (2).

5. The maximum allowable ampacity of neutral supported cable shall be as specified in **Tables 36A and 36B**.

6. A bonding conductor shall not be counted in determining the ampacities as provided for in Subrules (1) and (2).

7. The correction factors specified in this Rule:
   - a) Apply only to, and shall be determined from, the number of power and lighting conductors in a cable or raceway; and
   - b) Shall not apply to conductors installed in auxiliary gutters.

8. The ambient correction factors of Table 5A shall apply where conductors are installed in an ambient exceeding or anticipated to exceed 30ºC.

9. Where the free air spacing between adjacent single-conductor cables is maintained at not less than 25% nor more than 100% of the diameter of the largest cable, the ampacity shall be obtained from Subrules (1)(a) and (2)(a) for copper and aluminum conductors respectively, multiplied by the correction factor obtained from Table 5D.

10. Where up to and including four single-conductor cables in free air are spaced at less than 25% of the diameter of the largest conductor or cable, the ampacity shall be the same as that obtained from Subrules (1)(a) and (2)(a) for copper and aluminum conductors respectively, multiplied by the correction factor obtained from Table 5B.

11. Notwithstanding Subrule (10), where not more than four non-jacketed single-conductor mineral-insulated cables are grouped together in conformance with Rule 4-010(3) and are installed on a messenger or as open runs with a maintained free air space of not less than 2.15 times the diameter of the largest cable contained within the group and adjacent groups or cables, the ampacity of each conductor in the group shall be permitted to be determined in accordance with Subrule (1)(a) without applying the correction factors of Table 5B.

12. More than four single-conductor cables in free air, when spaced at less than 25% of the largest cable diameter, shall have an ampacity obtained from Tables 2 and 4 for copper and aluminum conductors respectively, multiplied by the correction factor obtained from Table 5C based on the total number of conductors.

13. Notwithstanding Subrule (12), when the length of a single-conductor cable run spaced at less than 25% of the largest cable diameter is less than 600 mm, the correction factor from Table 5C shall not apply.

14. Where multi-conductor cables are run in contact for distances greater than 600 mm, the ampacity of the conductors shall be corrected by applying the correction factors in Table 5C based on the total number of conductors in the cables.

15. The ampacity of conductors of different temperature ratings installed in the same raceway shall be determined on the basis of the conductor having the lowest temperature rating.

16. The ampacity of conductors added to a raceway and the ampacity of the conductors already in the raceway shall be determined in accordance with the applicable Subrules.

17. Where more than one ampacity could apply for a given circuit of single-conductor or multi-conductor cables as a consequence of a transition from an underground portion to a portion above ground, the lower value shall apply except as permitted in Subrule (18).

18. Where the lower ampacity portion of a cable installation consisting of not more than four conductors in total does not exceed 10% of the circuit length or 3 m, whichever is less, the higher ampacity shall be permitted.

19. When the load factor of the load is less than 1.00 and is known or can be supported by documentation, the ampacity of conductors derived from Subrules (1)(d) and (2)(d) shall be permitted to be increased by application of that load factor in the calculation of the ampacity.

20. In consideration of the increased ampacity of any conductor derived in accordance with Subrule (19), no further factors based on load diversity shall be permitted.

21. The ampacity of nickel or nickel-clad conductors shall be calculated using the method described in IEEE 835.

22. The maximum allowable ampacity of bare or covered conductors in free air shall be as specified in Table 66.

23. Notwithstanding Rule 4-006, 3-wire 120/240 V and 120/208 V service conductors for single dwellings and feeder conductors supplying single dwelling units of row housing of apartment and similar buildings and terminating on equipment having a conductor termination temperature of not less than 75 °C shall be permitted to be sized in accordance with Table 39.

TABLE 1: *(See Rules 4-004, 4-006, 8-104, 12-2210, 12-2260, 26-142, 42-008, and 42-016 and Tables 5A, 5B, and 19.)*

ALLOWABLE AMPACITIES FOR SINGLE UNSHIELDED COPPER CONDUCTORS RATED NOT MORE THAN 5000 V, IN FREE AIR
(based on ambient temperature of 30°C*)

	Allowable Ampacity†					
Size AWG kcmil	60°C‡	75°C‡	90°C§	110°C‡ See Note (3)	125°C‡ See Note (3)	200°C‡ See Note (3)
14**	25	30	35	40	40	50
12**	30	35	40	45	45	55
10**	40	50	55	65	65	80
8	60	70	80	90	95	115
6	80	95	105	120	130	155
4	105	125	140	160	170	205
3	120	145	165	185	195	240
2	140	170	190	215	230	280
1	165	195	220	245	265	320
0	195	230	260	290	310	375
00	220	265	300	335	355	435
000	260	310	350	390	420	510
0000	300	360	405	455	485	590
250	340	405	455	510	545	–
300	370	445	500	560	600	–
350	425	505	570	640	680	–
400	455	545	615	690	735	–
500	520	620	700	785	835	–
600	580	690	780	870	930	–
700	630	755	850	955	1020	–
750	655	785	885	990	1060	–
800	680	815	920	1030	1100	–
900	730	870	980	1100	1175	–
1000	785	935	1055	1180	1260	–
1250	890	1065	1200	1345	–	–
1500	985	1175	1325	1485	–	–
1750	1070	1280	1445	1620	–	–
2000	1160	1385	1560	1750	–	–
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7

* *See Table SA for the correction factors to be applied to the values in Columns 2 to 7 for ambient temperatures over 30°C.*
† The ampacity of single-conductor aluminum-sheathed cable is based on the type of insulation used on the copper conductor.
‡ These are maximum allowable conductor temperatures for single conductors run in free air and may be used in determining the ampacity of other conductor types listed in Table 19 that are run in free air, as follows: From Table 19 determine the maximum allowable conductor temperature for that particular type, then from this Table determine the ampacity under the column of corresponding temperature rating.
§ These ratings are based on the use of 90°C insulation on the emerging conductors and for sealing. Where a deviation has been allowed in accordance with Rule 2-030, mineral-insulated cable may be used at a higher temperature without decrease in allowable ampacity, provided that insulation and sealing material approved for the higher temperature is used.
** See Rule 14-104(2).

NOTES:
1. The ratings of this Table may be applied to a conductor mounted on a plane surface of masonry, plaster, wood, or any material having a conductivity not less than 0.4 W/(m°C).
2. See Table 5B for correction factors where from two to four conductors are present and in contact.
3. These ampacities apply to bare wire or under special circumstances where the use of insulated conductors having this temperature rating is acceptable.

TABLE 2: *(See Rules 4-004, 8-104, 12-2210, 12-2260, 12-3034, 26-142, 42-008, and 42-016 and Tables 5A, 5C, 19, 39, and D3.)*

ALLOWABLE AMPACITIES FOR NOT MORE THAN THREE COPPER CONDUCTORS, RATED NOT MORE THAN 5000 V AND UNSHIELDED, IN RACEWAY OR CABLE
(based on ambient temperature of 30°C*)

	Allowable Ampacity††					
Size AWG kcmil	60°C‡	75°C‡	90°C‡*	110°C‡ See Note (3)	125°C‡ See Note (3)	200°C‡ See Note (3)
14§	15	20	25	25	30	35
12§	20	25	30	30	35	40
10§	30	35	40	45	45	60
8	40	50	55	65	65	80
6	55	65	75	80	90	110
4	70	85	95	105	115	140
3	85	100	115	125	135	165
2	95	115	130	145	155	190
1	110	130	145	165	175	215
0	125	150	170	190	200	245
00	145	175	195	220	235	290
000	165	200	225	255	270	330
0000	195	230	260	290	310	380
250	215	255	290	320	345	–
300	240	285	320	360	385	–
350	260	310	350	390	420	–
400	280	335	380	425	450	–
500	320	380	430	480	510	–
600	350	420	475	530	565	–
700	385	460	520	580	620	–
750	400	475	535	600	640	–
800	410	490	555	620	660	–
900	435	520	585	655	700	–
1000	455	545	615	690	735	–
1250	495	590	665	745	–	–
1500	520	625	705	790	–	–
1750	545	650	735	820	–	–
2000	560	665	750	840	–	–
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7

* *See Table 5A for the correction factors to be applied to the values in Columns 2 to 7 for ambient temperatures over 30°C.*
† The ampacity of aluminum-sheathed cable is based on the type of insulation used on the copper conductors.
‡ These are maximum allowable conductor temperatures for one, two, or three conductors run in a raceway, or two or three conductors run in a cable, and may be used in determining the ampacity of other conductor types listed in Table 19, which are so run, as follows: From Table 19 determine the maximum allowable conductor temperature for that particular type, then from this Table determine the ampacity under the column of corresponding temperature rating.
§ See Rule 14-104(2).
** For mineral-insulated cables, these ratings are based on the use of 90°C insulation on the emerging conductors and for sealing. Where a deviation has been allowed in accordance with Rule 2-030, mineral insulated cable may be used at a higher temperature without decrease in allowable ampacity, provided that insulation and sealing material approved for the higher temperature is used.
†† See Table 5C for the correction factors to be applied to the values in Columns 2 to 7 where there are more than three conductors in a run of raceway or cable.

NOTES:
1. These ampacities apply to bare wire or under special circumstances where the use of insulated conductors having this temperature rating is acceptable.

TABLE 3: *(See Rules 4-004, 8-104, 12-2210, 12-2260, 26-142, 42-008, and 42-016 and Tables 5A, 5B and 19.)*

ALLOWABLE AMPACITIES FOR SINGLE UNSHIELDED ALUMINUM CONDUCTORS, RATED NOT MORE THAN 5000 V, IN FREE AIR
(based on ambient temperature of 30°C*)

	Allowable Ampacity†					
Size AWG kcmil	60°C‡	75°C‡	90°C‡	110°C‡ See Note (3)	125°C‡ See Note (3)	200°C‡ See Note (3)
12§	25	30	35	40	40	50
10§	35	40	45	50	55	65
8	45	55	60	70	75	90
6	65	75	85	95	100	125
4	85	100	115	125	135	165
3	95	115	130	145	155	190
2	115	135	150	170	180	220
1	130	155	175	195	210	255
0	150	180	205	225	245	295
00	175	210	235	265	285	345
000	200	240	270	305	325	395
0000	235	280	315	355	375	460
250	265	315	355	400	425	–
300	295	350	395	440	470	–
350	330	395	445	500	535	–
400	355	425	480	535	575	–
500	405	485	545	615	655	–
600	455	545	615	690	735	–
700	500	595	670	750	800	–
750	520	620	700	785	835	–
800	540	645	725	815	870	–
900	585	700	790	885	945	–
1000	630	750	845	950	1010	–
1250	715	855	965	1080	–	–
1500	795	950	1070	1200	–	–
1750	880	1050	1185	1325	–	–
2000	965	1150	1295	1455	–	–
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7

* *See Table 5A for the correction factors to be applied to the values in Columns 2 to 7 for ambient temperatures over 30°C.*

† The ampacity of single-conductor aluminum-sheathed cable is based on the type of insulation used on the aluminum conductor.

‡ These are maximum allowable conductor temperatures for single conductors run in free air and may be used in determining the ampacity of other conductor types listed in Table 19 that are run in free air, as follows: From Table 19 determine the maximum allowable conductor temperature for that particular type, then from this Table determine the ampacity under the column of corresponding temperature rating.

§ See Rule 14-104(2).

NOTES:
1. The ratings of this Table may be applied to a conductor mounted on a plane surface of masonry, plaster, wood, or any material having a conductivity not less than 0.4 W/m°C).
2. For correction factors where from 2 to 4 conductors are present and in contact, see Table 5B.
3. These ampacities apply to bare wire or under special circumstances where the use of insulated conductors having this temperature rating is acceptable.

TABLE 4: *(See Rules 4-004, 8-104, 12-2210, 26-142, 42-008, and 42-016 and Tables 5A and 5C.)*

ALLOWABLE AMPACITIES FOR NOT MORE THAN THREE ALUMINUM CONDUCTORS, RATED NOT MORE THAN 5000 V AND UNSHIELDED, IN RACEWAY OR CABLE
(based on ambient temperature of 30°C*)

	Allowable Ampacity†§					
Size AWG kcmil	**60°C‡**	**75°C‡**	**90°C‡**	**110°C‡ See Note (3)**	**125°C‡ See Note (3)**	**200°C‡ See Note (3)**
12**	15	20	25	25	25	35
10**	25	30	35	40	40	50
8	35	40	45	50	55	65
6	40	50	55	65	70	80
4	55	65	75	80	90	105
3	65	75	85	95	100	125
2	75	90	100	115	120	150
1	85	100	115	125	135	165
0	100	120	135	150	160	195
00	115	135	150	170	180	220
000	130	155	175	195	210	255
0000	150	180	205	225	245	295
250	170	205	230	260	275	–
300	195	230	260	290	310	–
350	210	250	280	315	335	–
400	225	270	305	340	365	–
500	260	310	350	390	420	–
600	285	340	385	430	460	–
700	315	375	425	475	505	–
750	320	385	435	485	520	–
800	330	395	445	500	535	–
900	355	425	480	535	575	–
1000	375	445	500	560	600	–
1250	405	485	545	615	–	–
1500	435	520	585	655	–	–
1750	455	545	615	690	–	–
2000	470	560	630	710	–	–
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7

* *See Table 5A for the correction factors to be applied to the values in Columns 2 to 7 for ambient temperatures over 30°C.*
† The ampacity of aluminum-sheathed cable is based on the type of insulation used on the aluminum conductor.
‡ These are maximum allowable conductor temperatures for 1, 2, or 3 conductors run in raceway, or 2 or 3 conductors run in a cable and may be used in determining the ampacity of other conductor types in Table 19, which are so run, as follows: From Table 19 determine the maximum allowable conductor temperature for that particular type; then from Table 4 determine the ampacity under the column of corresponding temperature rating
§ See table 5C for the correction factors to be applied to the values in Columns 2 to 7 where there are more than 3 conductors in a run of raceway or cable.
** See Rule 14-104(2).

NOTE:
1. These ampacities apply to bare wire or under special circumstances where the use of insulated conductors having this temperature rating is acceptable.

TABLE 5A: *(See Rules 4-004(8), 12-2210 and 12-2260 and Tables 1 to 4, 57, and 58.)*

CORRECTION FACTORS APPLYING TO TABLES 1, 2, 3 AND 4

Ampacity Correction Factors for Ambient Temperatures above 30°C

Ambient temperature, °C	Correction Factor								
	Insulation temperature rating, °C								
	60	75	90	105*	110*	125*	150*	200*	250*
35	0.91	0.94	0.96	0.97	0.97	0.97	0.98	0.99	0.99
40	0.82	0.88	0.91	0.93	0.94	0.95	0.96	0.97	0.98
45	0.71	0.82	0.87	0.89	0.90	0.92	0.94	0.95	0.97
50	0.58	0.75	0.82	0.86	0.87	0.89	0.91	0.94	0.95
55	0.41	0.67	0.76	0.82	0.83	0.86	0.89	0.92	0.94
60	–	0.58	0.71	0.77	0.79	0.83	0.87	0.91	0.93
65	–	0.47	0.65	0.73	0.75	0.79	0.84	0.89	0.92
70	–	0.33	0.58	0.68	0.71	0.76	0.82	0.87	0.90
75	–	–	0.50	0.63	0.66	0.73	0.79	0.86	0.89
80	–	–	0.41	0.58	0.61	0.69	0.76	0.84	0.88
90	–	–	–	0.45	0.50	0.61	0.71	0.80	0.85
100	–	–	–	0.26	0.35	0.51	0.65	0.77	0.83
110	–	–	–	–	–	0.40	0.58	0.73	0.80
120	–	–	–	–	–	0.23	0.50	0.69	0.77
130	–	–	–	–	–	–	0.41	0.64	0.74
140	–	–	–	–	–	–	0.29	0.59	0.71
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10

* *These ampacities are applicable only under special circumstances where the use of insulated conductors having this temperature rating is acceptable.*

NOTES:

1. These correction factors apply to Tables 1, 2, 3, and 4. The correction factors in Column 2 also apply to Table 57.
2. The ampacity of a given conductor type at higher ambient temperatures is obtained by multiplying the appropriate value from Table 1, 2, 3, or 4 by the correction factor for that higher temperature.

TABLE 5B: *(See 4-004 and 12-2210 and Tables 1 and 3.)*

CORRECTION FACTORS FOR TABLES 1 AND 3

(where from two to four single conductors are present and spaced less than 25% of the largest cable diameter)

Number of Conductors	Correction Factors
2	0.90
3	0.85
4	0.80

NOTES:

1. Where four conductors form three-phase-with-neutral system, the values for three conductors may be used. Where three conductors form a single-phase, 3-wire system, the values for two conductors shall be permitted to be used.
2. Where more than four conductors are in contact, the ratings for conductors in raceways shall be used.

TABLE 5C: *(See Rules 4-004 and 12-2210 and Tables 2 and 4.)*

AMPACITY CORRECTION FACTORS FOR TABLES 2 AND 4

Number of Conductors	Correction Factors
1 - 3	1.00
4 - 6	0.80
7 - 24	0.70
25 - 42	0.60
43 and up	0.50

TABLE 5D: *(See Rules 4-004 and 12-2210 and Table 12E.)*

CURRENT RATING CORRECTION FACTORS WHERE SPACINGS ARE MAINTAINED (in ventilated and ladder-type cable trays)

Number of Conductors or Cables Horizontally	1	2	3	4	5	6
Number vertically (layers)						
1	1.00	0.93	0.87	0.84	0.83	0.82
2	0.89	0.83	0.79	0.76	0.75	0.74

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