Manual for design of Guardrails

for

Designers, Engineers, Architects, Contractors, Installers

www.allium.com

Table of contents

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Introduction

Railings are systems designed to protect people in specific spaces such as balconies, terraces and stairways. They include vertical load-bearing elements, posts, horizontal load-bearing elements, handrails with complementary elements such as balusters or tempered glass panels.

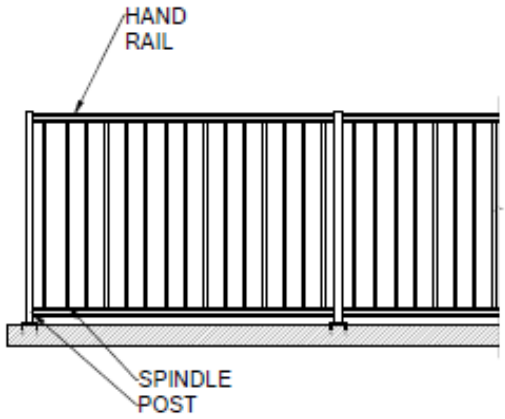


Figure 1. Main elements of a guardrail system

Guardrails are made of different materials such as wood, steel, aluminum, plastic or of two or more of these materials (hybrid). Over the past years, the use of aluminum in railings has increased due to its attractive characteristics such as lightness, corrosion-proof, weatherproof, environmental deterioration resistance, etc.

Since 1989, Les entreprises Allium manufacture customized railings and other products that are all made of aluminum and coated with highly resistant acrylic enamel. These Allium products will always keep their impeccable finish and original colour. Also, contrary to other materials, they will remain sturdy and strong. Unique fabrication processes, a rigorous quality control at all production steps, a meticulous finish and attentive care make these products very attractive.

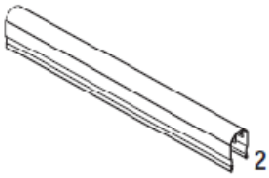
The purpose of the manual is to help architects, designers, engineers, contractors and installers choose guardrail system elements based on their needs and select the appropriate needed elements especially posts, handrails and spacing between posts.

Types of Guardrail system

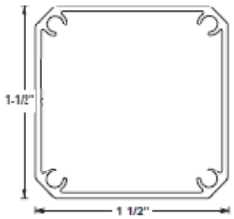
Série/Series 100

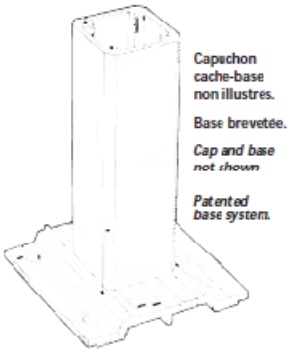
SPÉCIFICATIONS/*SPECIFICATIONS*

Main courante / *Handrail*

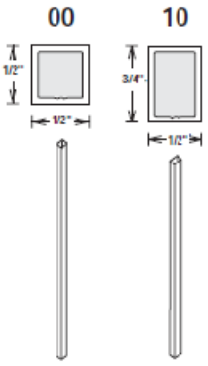


Poteau / *Post*

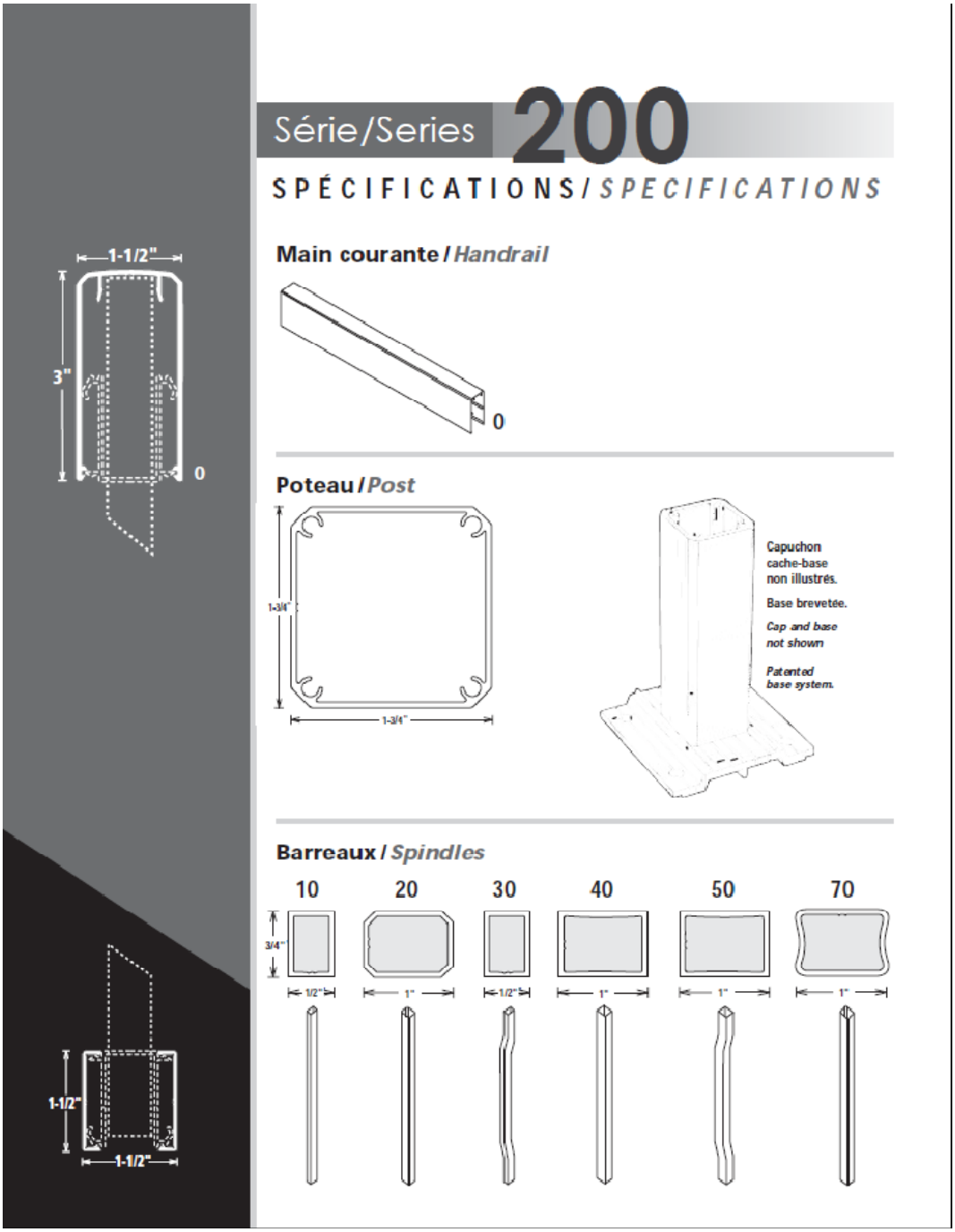




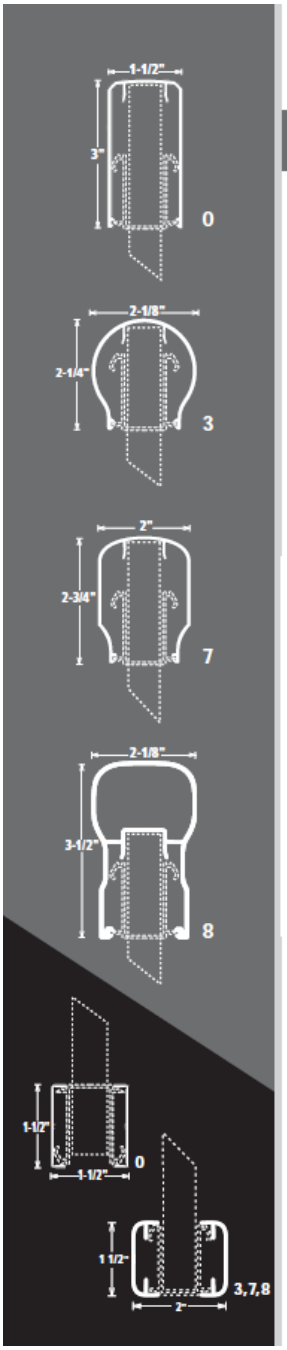
Barreaux / *Spindles*




Série/Series 200
GARDE-CORPS / RAILINGS
Disponible en double traverse
Available as double rail
MAIN COURANTE No 0
HANDRAIL
1-1/2" x 3"
BARREAUX / SPINDLES
POTEAU / POST
1-3/4" x 1-3/4"
10
20
30
40
50
70
1/2" x 3/4"
1" x 3/4"
1/2" x 3/4"
1" x 3/4"
1" x 3/4"
1" x 3/4"


Série/Series 200
SPÉCIFICATIONS/SPECIFICATIONS
1-1/2"
3"
0
Main courante/Handrail
0
Poteau/Post
1-3/4"
1-3/4"
Capuchon cache-base non illustrés.
Base brevetée.
Cap and base not shown
Patented base system.
Barreaux/Spindles
10
20
30
40
50
70
3/4"
1/2"
1"
1/2"
1"
1"
1"
1-1/2"
1-1/2"

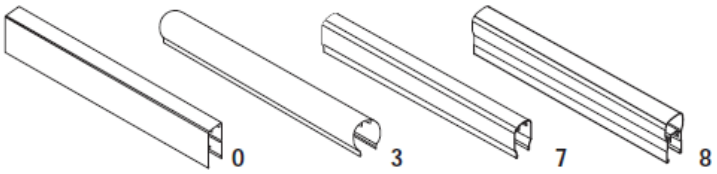

Série/Series 300
GARDE-CORPS/RAILINGS
Disponible en double traverse
Available as double rail
MAIN COURANTE No 0
HANDRAIL
1-1/2" x 3"
MAIN COURANTE No 3
HANDRAIL
2 1/8" x 2 1/4"
MAIN COURANTE No 7
HANDRAIL
2" x 2-3/4"
MAIN COURANTE No 8
HANDRAIL
2-1/8" x 3-1/2"
BARREAUX / SPINDLES
POTEAU / POST
2-3/4" x 2-3/4"
10
20
30
40
50
70
1/2" x 3/4"
1" x 3/4"
1/2" x 3/4"
1" x 3/4"
1" x 3/4"
1" x 3/4"



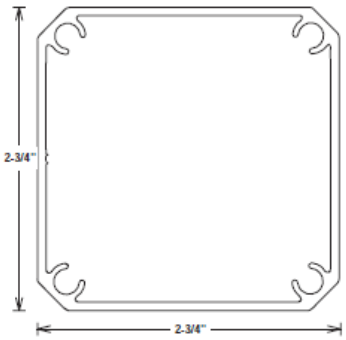
Série/Series 300

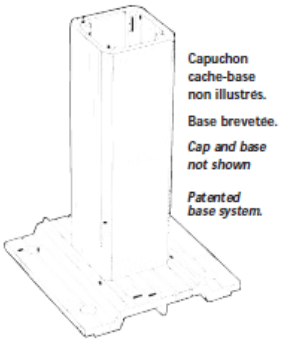
SPÉCIFICATIONS / *SPECIFICATIONS*

Mains courantes / *Handrails*



Poteau / *Post*





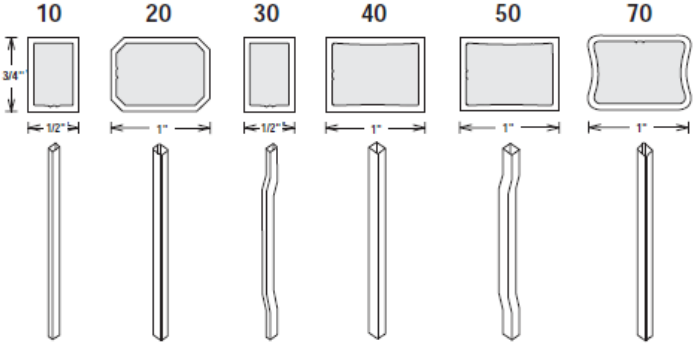
Capuchon cache-base non illustrés.

Base brevetée.

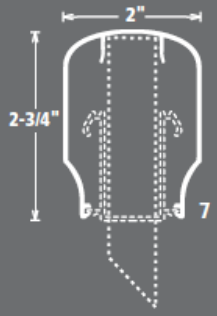
Cap and base not shown

Patented base system.

Barreaux / *Spindles*



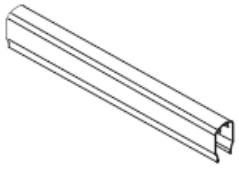

Série/Series ÉLÉGANCE
GARDE-CORPS / RAILINGS
MAIN COURANTE No 7
HANDRAIL
2" x 2-3/4"
POTEAU / POST
2-3/4" x 2-3/4"
BARREAU / SPINDLE NO 80



Série/Series ÉLÉGANCE

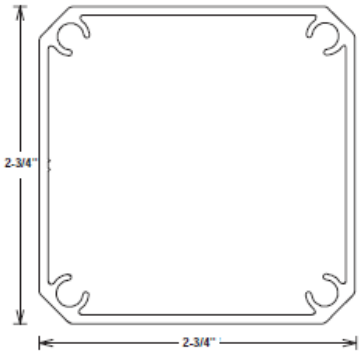
SPÉCIFICATIONS/*SPECIFICATIONS*

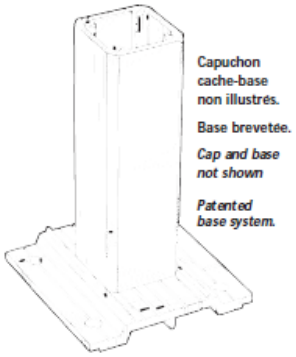
Main courante/*Handrail*



7

Poteau/*Post*





Capuchon cache-base non illustrés.

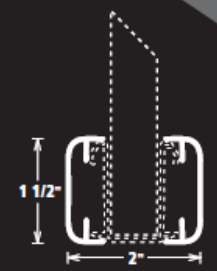
Base brevetée.

Cap and base not shown

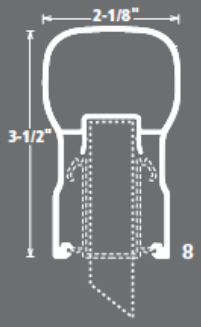
Patented base system.

Barreau/*Spindle*

80



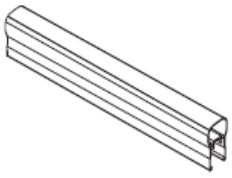

Série/Series HÉRITAGE
GARDE-CORPS/RAILINGS
MAIN COURANTE No 8
HANDRAIL
2-1/8" x 3-1/2"
POTEAU/POST
2-3/4" x 2-3/4"
BARREAU/SPINDLE NO 90



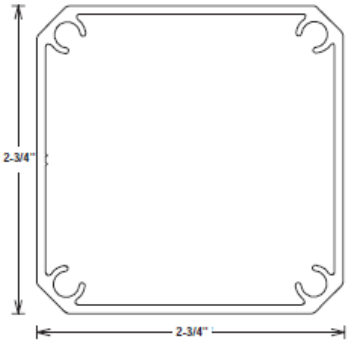
Série/Series HÉRITAGE

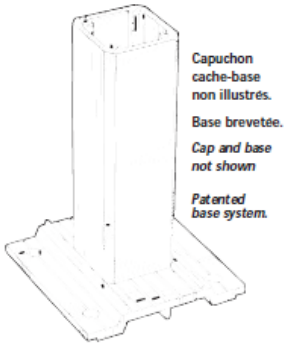
SPÉCIFICATIONS/*SPECIFICATIONS*

Main courante / *Handrail*



Poteau / *Post*





Capuchon cache-base non illustrés.

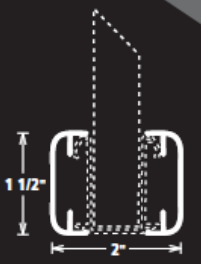
Base brevetée.

Cap and base not shown

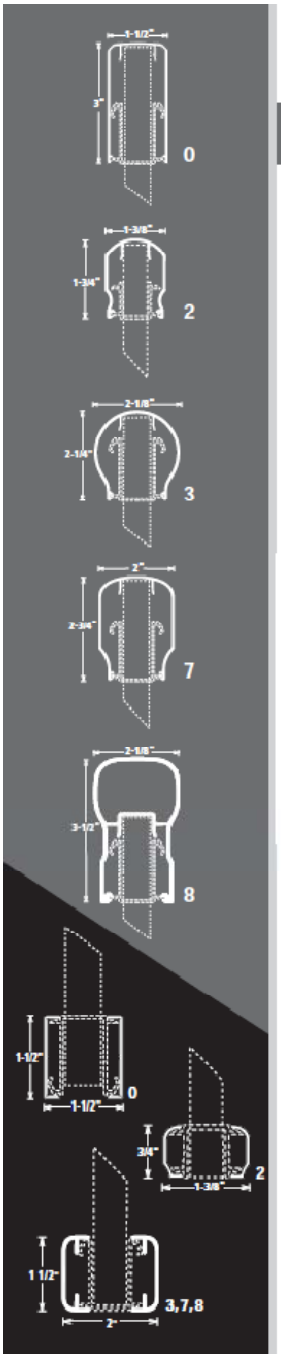
Patented base system.

Barreau / *Spindle*

90



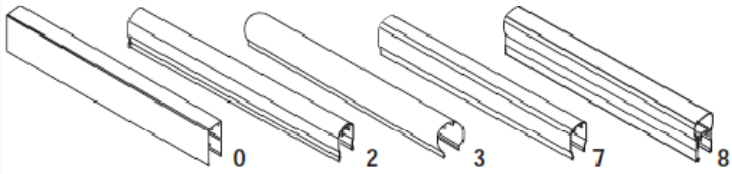

Série/Series SÉVILLE
GARDE-CORPS/RAILINGS
MAIN COURANTE No 0
HANDRAIL
1-1/2" x 3"
POTEAU/POST
No 300 2-3/4" x 2-3/4"
No 200 1-3/4" x 1-3/4"
No 100 1-1/2" x 1-1/2"
MAIN COURANTE No 2
HANDRAIL
1-3/8" x 1-3/4"
BARREAUX/SPINDLES
10
20
40
70
MAIN COURANTE No 3
HANDRAIL
2-1/8" x 2-1/4"
MAIN COURANTE No 7
HANDRAIL
2" x 2-3/4"
MAIN COURANTE No 8
HANDRAIL
2-1/8" x 3-1/2"
1/2" x 3/4"
1" x 3/4"
1" x 3/4"
1" x 3/4"



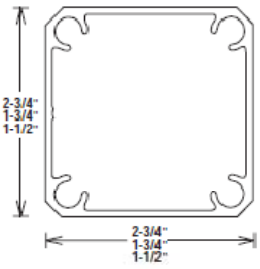
Série/Series SÉVILLE

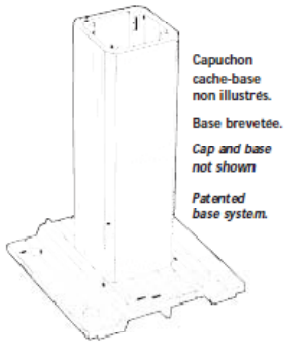
SPÉCIFICATIONS / *SPECIFICATIONS*

Mains courantes / *Handrails*



Poteau / *Post*





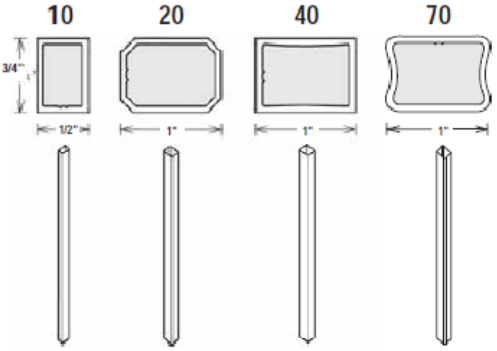
Capuchon cache-base non illustrés.

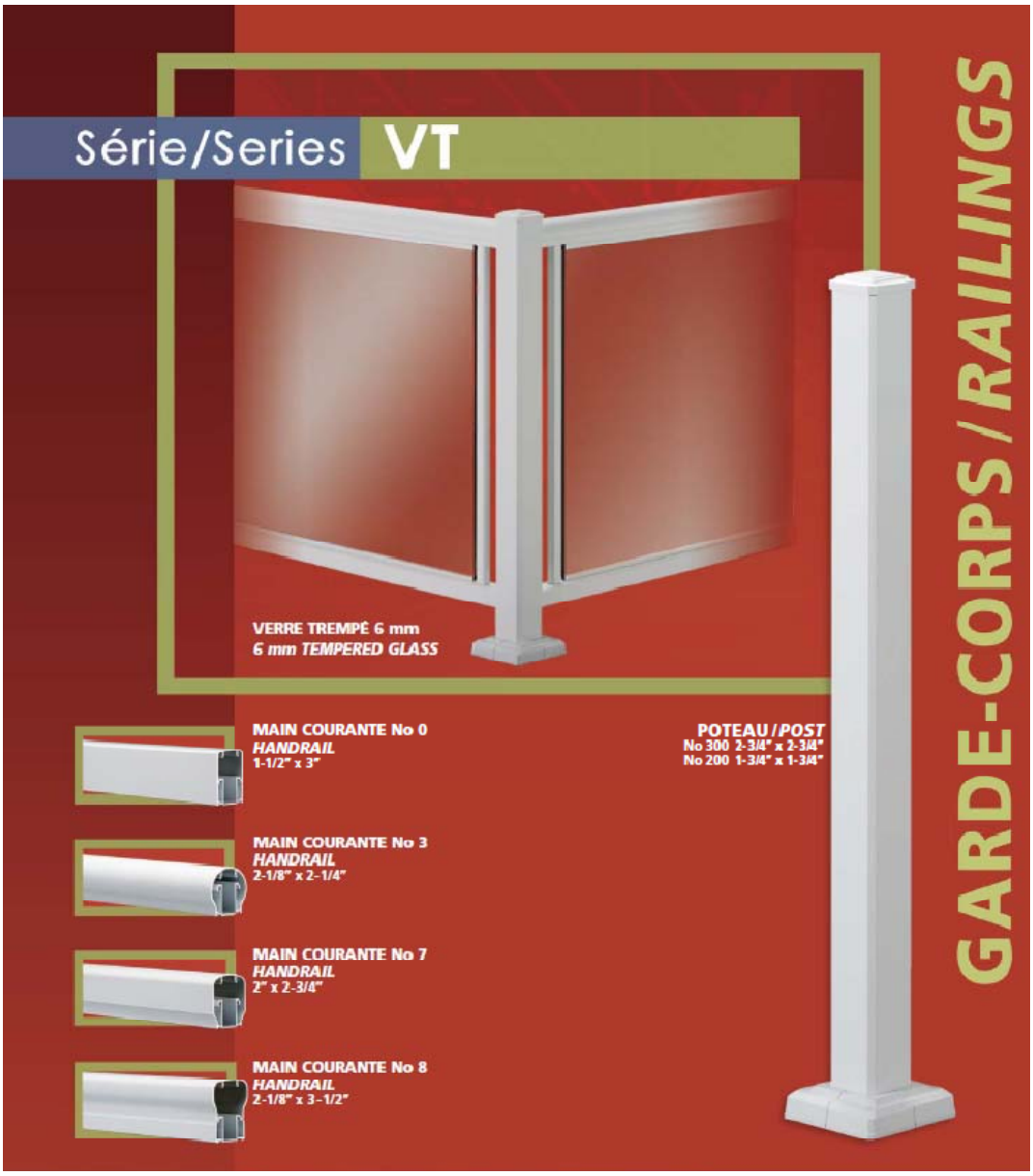
Base brevetée.

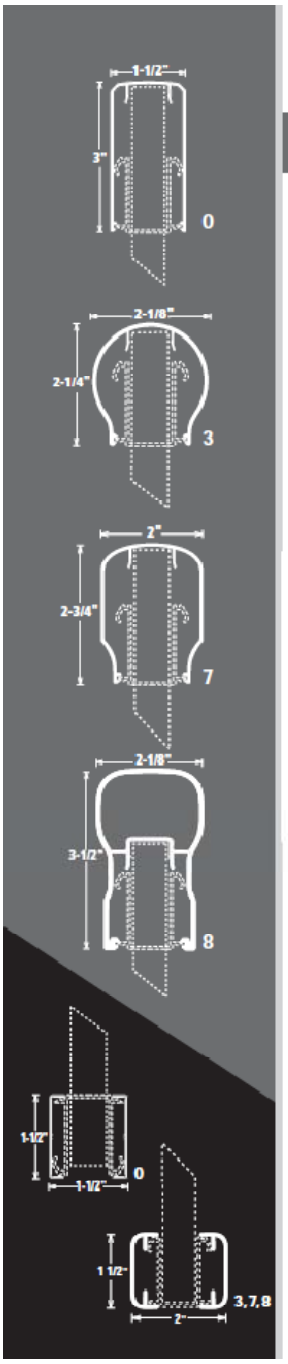
Cap and base not shown

Patented base system.

Barreaux / *Spindles*



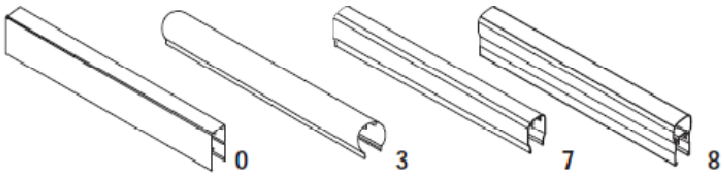

Série/Series VT
GARDE-CORPS / RAILINGS
VERRE TREMPÉ 6 mm
6 mm TEMPERED GLASS
MAIN COURANTE No 0
HANDRAIL
1-1/2" x 3"
MAIN COURANTE No 3
HANDRAIL
2-1/8" x 2-1/4"
MAIN COURANTE No 7
HANDRAIL
2" x 2-3/4"
MAIN COURANTE No 8
HANDRAIL
2-1/8" x 3-1/2"
POTEAU / POST
No 300 2-3/4" x 2-3/4"
No 200 1-3/4" x 1-3/4"



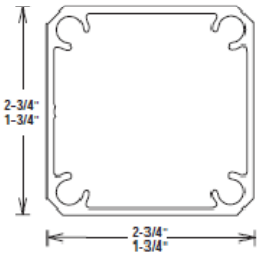
Série/Series VERRE TREMPÉ

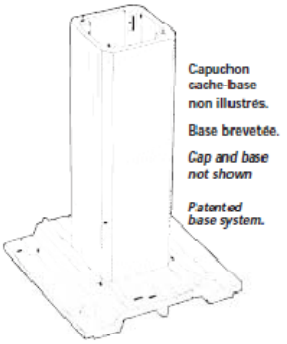
SPÉCIFICATIONS / *SPECIFICATIONS*

Mains courantes / *Handrails*



Poteau / *Post*





Capuchon cache-base non illustrés.

Base brevetée.

Cap and base not shown

Patented base system.

Verre / *Glass*

COULEURS / *COLORS*			
6 mm			
CLAIR *CLEAR*	GRIS *GREY*	BRONZE *BRONZE*	VERT *GREEN*

General Requirements according to Standards

The National Building Code of Canada (NBCC 2010) sets certain general non structural requirements with regard to fire protection in Chapter 3.4, including fire protection, occupants' safety and accessibility, requirements regarding emergency exits (see annex I). It is also recommended to refer to Part 9 of the National Building Code of Canada 2010 regarding small buildings.

Mechanical properties

Mechanical characteristics of the elements of the guardrail system are in accordance with standard CAN/CSA-S157-05 Strength Design in Aluminum. The elements of the guardrail system according to the manufacturer's specifications are made of alloy 6360 –T6 with F_u=205 MPa et F_y=170 MPa.

Physical properties

Physical properties of alloys are the following, according to standard CSA S175-05 :

- Coefficient of linear thermal expansion, $\alpha = 24 \times 10^{-6}$ /°C
- Modulus of elasticity, E= 70,000 MPa
- Poisson's Ratio, ν=0,33
- Shear Modulus, G= 26,000 MPa
- Density, ρ=2700 kg/m^3

The section of elements commonly used for Allium products is included on the table 1 and 2.

Element	Post 1 ½ x1 ½	Post 1 ¾ x 1 ¾	Post 2 ¾ x 2 ¾
Alloy	6360	6360	6360
Area (mm^2)	282.4	308.0	551.0
Linear masse (Kg/m)	0.763	0.832	1.489
Total perimeter (mm)	334.6	379.9	586.5
Ixx $10^6(mm^4)$	1.58	4.32	15.89
Sxx 10^3 (mm^3)	166.0	194.0	455.0
Iyy $10^6(mm^4)$	1.58	4.32	15.89
Syy 10^3 (mm^3)	166.0	194.0	455.0

Ixx, Iyy : moment of inertia of the section based on x and y axis respectively
Sxx, Syy : section module based on x and y axis respectively

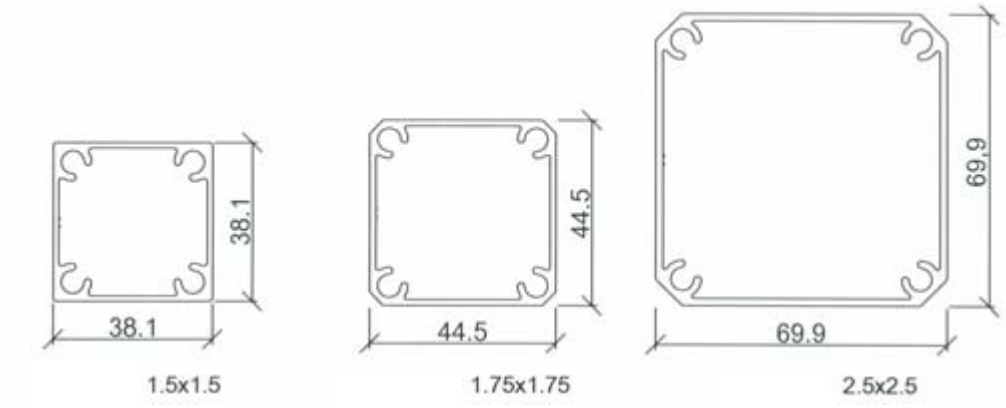


Table 1 Physical properties of **Posts**

Element	No.0	No.02	No.03	No.07	No.08
Alloy	6360	6360	6360	6360	6360
Area (mm^2)	353.0	192.4	277.0	327.0	458.0
Linear masse (Kg/m)	0.954	0.520	0.747	0.884	1.238
Total perimeter (mm)	413.8	271.0	341.2	403.6	504.2
Ixx $10^6(mm^4)$	5.26	2.74	2.72	3.51	6.86
Sxx 10^3 (mm^3)	266	157.4	100.9	138.3	254.6
Iyy $10^6(mm^4)$	4.29	3.40	0.85	3.6	5.9
Syy 10^3 (mm^3)	9.8	131.7	25.6	87.7	115.9

Ixx, Iyy : moment of inertia of the section based on x and y axis respectively
Sxx, Syy : section module based on x and y axis respectively

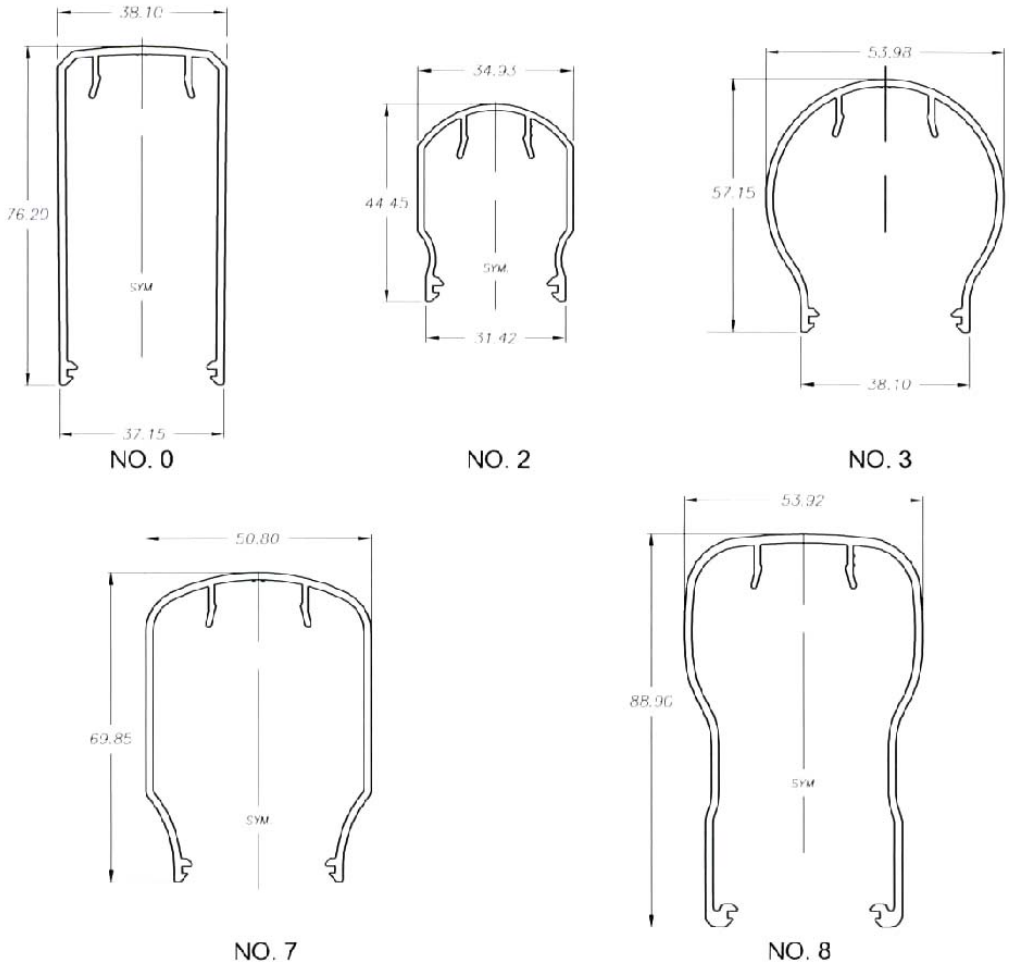


Table 2 Physical properties of **handrails**

Loading

Loads applied to the railing system, according to the National Building Code of Canada 2010, are indicated in Chapter 4, Calculation Method. Loads to consider are live loads caused by use and wind loads for the Tempered glass series. Other loads such as a permanent load, snow load, and seismic load are insignificant because of their low range compared to the overcharge caused by use or wind.

Live load

Refer to article 4.1.5.14 that follows:

4.1.5.14 Guardrails

- The minimum specified load applied horizontally, externally or internally, on the required minimum height of a required railing is:

- *3,0 kN/m for open tribunes without fixed seats and for evacuation averages of tribunes, stadium, grandstands and arenas;*
- *1,0 kN concentrated at any location on the railing, access bridge to equipment platforms, adjoining stairways and other similar locations where it is unlikely that a large number of persons meet; and*
- *0,75 kN/m or 1,0 kN concentrated at any location on the railing, if the situation applies to locations other than those described in paragraphs a) and b).*

- Constituent elements of railings, including solid panels and vertical bars must be designed to resist to a load of 0,5 kN on an area of 100 mm laterally, at any location of the element or elements where it produces a maximum effect.

- It is not mandatory to consider that the loads indicated in paragraph 2) act simultaneously with those indicated in paragraphs 1) and 4).

- The minimum required specified load applied vertically on the top part of the required railing is 1,5 kN/m and it is not mandatory to consider that this load will occur simultaneously with the horizontal load indicated in paragraph 1).

Specified loads for handrails are indicated in paragraphs 3.4.6.5. 12).

Wind loads

For the railing system with tempered glass (tempered glass series), the wind load must be considered according to Part 4 of the National Building Code as well as the Code commentary.

$$P= I_w.q.C_e.C_g.C_p$$

p is the static pressure applied vertically on the glass area, Iw is the risk coefficient that is equal to 1 for the calculation of the ultimate limit state and equal to 0.75 for the calculation of the service limit state, q is the reference dynamic pressure that fluctuates according to the region (indicated in Volume II of the NBC 2010). C_e is the wind exposure coefficient that may vary depending on the height of the railing.

For a guard rail measuring 1.06 m (42 in) high with a maximum wind base pressure of q=0.70 kPa (for example, in Montreal q=0.42 kPa and in Quebec q=0.41kPa), a maximum C_e value of 1.0 and maximum $C_g.C_p$. values of 1.8, the value of the factored uniform load applied to the guard rail is 0.93 kN/m which is lower than the minimal live load of 1.125 kN/m recommended in the standard. Therefore, we can say that, in all cases where the height of the guard rail is lower than 1.06 m (42 in), there is no need to take into consideration the effect of the wind. If the height of the guard rail exceeds 1.06m (42 in), modification coefficients are applied to the wind load (table 5).

Loads combinations

In cases where the only load is the overload caused by use, according to NBC 2010, that is any type of railing system except for tempered glass, the combination is as follows:

- Resistance to ultimate limit states calculation: 1.5L

- Deflection to service limit states calculation: 1.0 L

For tempered glass railings, the following combinations are considered:

- Resistance to ultimate limit states calculation: max(1.5L,1.4W)
- Deflection to service limit states calculation: max(1.0 L,1.0W)

Structural analyses for guardrails systems

The load distribution and structural analysis of various railing systems are established based on the following parameters:

- The types of railing elements such as handrails, posts, base of handrails, bottom railing and bars
- The geometry of the railing system such as the height and space between posts
- The limit conditions: type of connection and attachments at the end of the railing system and rigidity of post anchorage in the ground
- The continuity of handrails, the relative rigidity of handrails and posts, the type of bars and spacing, etc.

Considering the following conditions and according to the loads specified earlier, the different loads are calculated based on the Strength Design in Aluminum Calculation Method according to CAN/CSA-S157-05 standard. Design tables take into consideration the types of posts and spacing. Also, design tables are used for a 1.06m (42 in) height. For a different height, spacing specified on the each table is modified according to the modification height(table 5).

Steps of design

1. Choose the type of guard rail system.
2. If the guard rail is used:
    a. in a public space (4.3.3.3) consider the live load 3 kN/m
    b. otherwise, use 0.75 kN/m
3. According to load combinations, calculate the factored load
4. To select the spacing:
    a. If the factored load is 1.125 kN/m use table 1, according to selected post, choose economic number of section (n) and spacing(s).
    b. If the load is 4 kN/m, use table 2 use, choose the economic number of section (n) and spacing (s)
5. If the height of the guard rail differs from 1.06m (42 in), modify the spacing according to chart 5
6. In case of guard rails with tempered glass
    a. the wind effect is insignificant if the height is equal to or less than 1.06 m (42 in), go to steps 2 to 4
    b. Apply the modification coefficients for the wind load according to table 5, in the case where the height of guard rail is greater than 1.06 m (42 in).

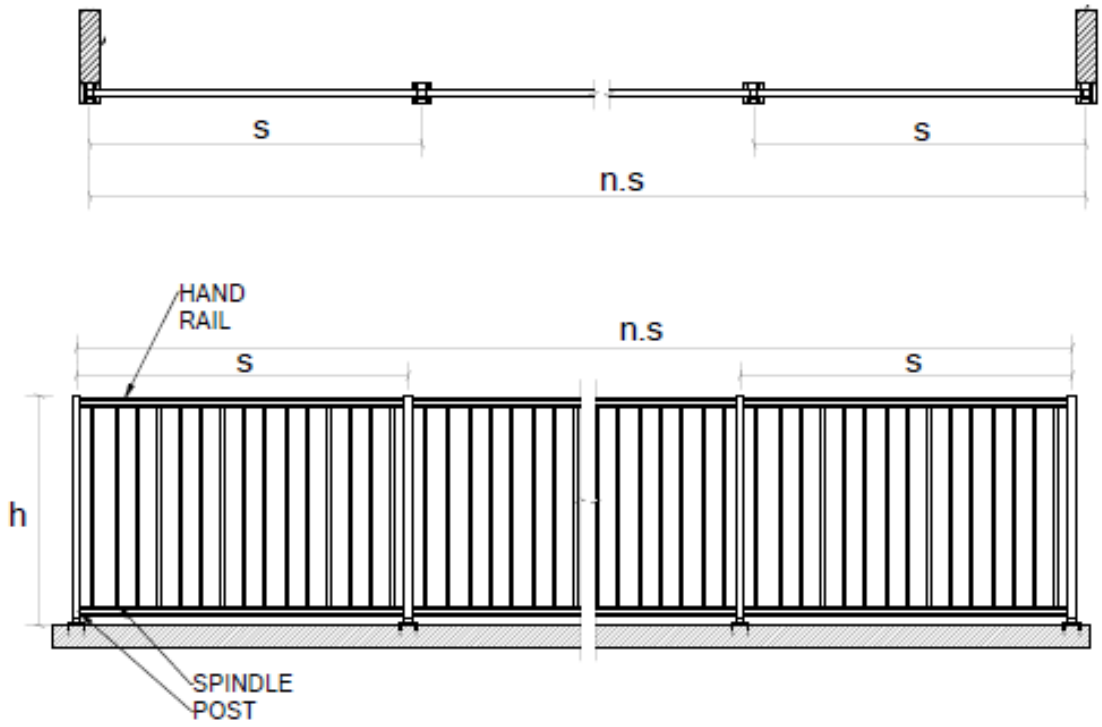


Figure 2 Parameters of guardrail systems for design table

Post 1 ½ x 1 ½

Number of section n	1	2	3	≥4
Posts spacing *s mm(in)*	2130 mm(84 *in*)	1778 mm(70 *in*)	1422 mm(56 *in*)	1067 mm(42 *in*)

post 1 ¾ x 1 ¾

Number of section n	1	2	3	≥4
Posts spacing *s mm(in)*	2439 mm(96 *in*)	2235 mm(88 *in*)	2032 mm(80 *in*)	1829 mm(72 *in*)

post 2 ¾ x 2 ¾

Number of section n	1	2	3	≥4
Posts spacing *s mm(in)*	2439 mm(96 *in*)	2439 mm(96 *in*)	2439 mm(96 *in*)	2439 mm(96 *in*)

Table 3 Design table
Factored load 1.125 kN/m(non factored load 0.75 kN/m)

post 2 ¾ x 2 ¾

Number of section n	1	2	3	≥4
Posts spacing *s mm(in)*	1524 mm(60 in)	1270 mm(50 in)	1016 mm(40 in)	762 mm(30 in)

Table 4 Design table
Factored load 4.0 kN/m(non factored load 3.0 kN/m)

Height	Height coefficient for live load	Height coefficient for wind load
500 mm (20 po)	2.1	-
600 mm (24 po)	1.75	-
700 mm (28 po)	1.50	-
800 mm (32)	1.30	-
900 mm (36 po)	1.20	-
1067 mm (42 po)	1.0	1.0
1100 mm (44 po)	0.95	0.90
1200 mm (48 po)	0.88	0.76
1300 mm (52 po)	0.80	0.65
1400 mm (56 po)	0.75	0.56
1500 mm (60 po)	0.70	0.50
2000 mm (78 po)	0.54	0.30

Table 5. Modification coefficient for height of guardrail system

Anchorage

Proper anchoring of the base posts to the deck flooring is important to ensure adequate performance of the railing system. The fasteners provided to anchor the Allium Railing System's base posts may not necessarily be appropriate for all applications or may not necessarily comply with all building codes. Therefore we highly recommend consulting with your local building officials before beginning work. No representation or warranty is given that your particular application of these products complies with relevant building codes or that the fasteners provided or used are appropriate for your application.

Lab Test Results

Certain Allium guard rail systems are tested in specialized laboratories. Results of tests performed according to existing standards show a similarity between our design procedures and lab test results.

Bodycote TECHNITROL • ECO

BODYCOTETECHNITROLINC. • 121, BOUL.HYMUS, POINTE-CLAIRE, QUÉBEC H9R 1E6 • TÉL: (514)697-3273 • FAX:(514)697-2890

Pointe-Claire, 19 juin 1998

Les Entreprises Allium
8100, rue de l'Industrie
Anjou, **(Québec)**
HIJ IS7

À l'attention de: M. Gaétan Beaudry

Objet: Description de l'échantillon testé au rapport #98 37074-2.

M. Beaudry,

Par la présente, je vous précise que le modèle de garde-corps en aluminium dont il est question au rapport # 98-37074-2, correspond à la série 210, tel que spécifié dans la documentation que vous nous avez fourni.

Les caractéristiques de **la** série 210 sont les suivantes:

-Barreaux:	I/2 " x 314"
-Poteaux:	1 3/4 x 1 3/4"
-Main courante:	1 1/2" x 3"
-Partie inférieure:	1 1/2 x 1 1/2 "

En espérant que le tout sera à votre entière satisfaction.

Veuillez agréer, M. Beaudry, l'expression de nos salutattions distinguées.

Mario Pannese. B.Arch.
Superviseur - Produits industriels et de consommation

Bodycote TECHNITROL • ECO

BODYCOTE TECHNITROL INC. • 121, BOUL. HYMUS, POINTE-CLAIRE, QUÉBEC H9R 1E6 • TÉL.: (514) 697-3273 • FAX: (514) 697-2090

BODYCOTE TECHNITROL INC.
Rapport No. 98-37074-2
Date : 04 juin 1998

Client: Les Entreprises Allium
8100, rue de l'Industrie
Anjou, (Québec)
Canada, H1J 1S7

CERTIFICAT D'ANALYSES

1) **Modèle:** **Garde-corps d'aluminium 42" de hauteur et 96" de longueur (aucune autre information soumise)**

(Voir les photos en page suivante)

Note: Les pattes intermédiaires de l'échantillon soumis ont été modifiées par l'utilisation de boulons fixés de part en part du support au lieu des vis employées sur le premier échantillon.

Paramètres utilisés: article 4.1.10.1 du Code National du bâtiment du Canada-1995

a) **Charge verticale:**
100 X 8 pi.= 800 lbs (uniformément répartie)
Résultats:
Le garde-corps a soutenu le stress imposé par cette charge verticale.

b) **Charge horizontale:**
50 lbs/pi. X 8 pi.= 400 lbs (uniformément répartie)
Résultats:
Le garde-corps a soutenu le stress imposé par cette charge horizontale, bien que l'une des bases ait légèrement fléchi suite à l'application de la charge. (inclinaison approximative du poteau de 5 degrés par rapport à la verticale). Le garde-corps n'a pas perdu son intégrité structurale et a continué a jouer adéquatement son rôle de barrière suite à l'essai.

c) **Charge appliquée à un barreau:**
110 lbs, charge appliquée horizontalement au centre d'un barreau.
Résultats:
Le barreau a soutenu le stress imposé par cette charge horizontale.

Conclusion: Date: 25/05/1998
Le modèle de rampe décrit ci-haut rencontre les exigences de l'article 4.1.10.1 du Code National du Bâtiment du Canada-1995.

Bodycote TECHNITROL-ECO

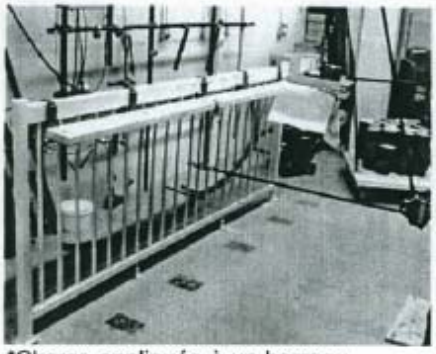
BODYCOTE TECHNITROL INC.
Rapport No. 98-37074-2
Date : 04 juin 1998

Client: Les Entreprises Allium
8100, rue de l'Industrie
Anjou, (Québec)
Canada, HIJ IS7

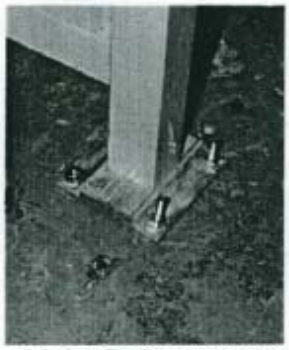
CERTIFICAT D'ANALYSES

•Charge verticale.

•Charge horizontale.



*Charge appliquée à un barreau.



. Légère flexion au centre de la base lors de l'essai de charge horizontale.

Mario Pannese, B.Arch.
Superviseur - Produits industriels et de consommation

Annex I

National Building Code (NBC 2011, Chapter 3 concerning fire protection, occupants' safety and accessibility and Section 3.4 emergency exit requirements):

3.4.6.5 Handrails

Stairways must include a handrail on at least one side and, if their width is equal to 1100 mm or more, it must include a handrail on each side.

1) *If the required width for a rail or flight of stairs exceeds 2200 mm, there must be one or more uninterrupted intermediary handrails between each landing and the distance between two handrails must not exceed 1650 mm.*
2) *Handrails must be easy to grab on their entire length and:*
   a) *if they include a circular section, they must have at least 30 mm or at the most 43 mm in diameter; or*
   b) *if they include a non circular section, they must have a perimeter of at least 100 mm and at the most 125 mm and a transversal section with the largest dimension measuring at the most 45 mm.*
3) *The height of the stairways handrails and ramps must be measured vertically starting from the top of the handrail:*
   a) *up to a tangent to the nosing of the stairs where the handrail is used (see note A-9.8.7.4.); or*
   b) *up to the surface of the ramp, floor or landing where the handrail is used.*

Subject to paragraphs 6) and 7), stairway handrails and ramps must have a height of:

a) at least 865 mm; and

b) at the most 965 mm.

6) It is not mandatory that installed handrails in addition to required handrails be in accordance with paragraph 5).

7) When railings are mandatory, the height of landing handrails must not exceed 1070 mm.

8) Except when they are interrupted by balustrades when changing direction or by doorways, at least one handrail must be continuous on the entire length of the stairway or ramp, including landings (see annex A).

9) Handrails must end in a way that will not block the circulation of pedestrians or will not create a risk (see note A-3.4.6.5 8).

10) Stairways and ramps must have at least one lateral handrail that extends horizontally over at least 300 mm on each end (see note A-3.4.6.5. 8).

11) The clearance between handrails and any surface located behind them must be:

a) at least 50 mm; or

b) equal to 60 mm if the surface located behind the handrails is rough or abrasive.

12) Handrails and their supports must be calculated and built to resist to the highest of the following loads:

a) a concentrated load of at least 0,9 kN applied at any location and in any direction, for all handrails; or

b) a consistent load of at least 0,7 kN/m applied in any direction, for handrails that are not located inside an apartment.

13) Handrails must be installed on both sides of a ramp.

3.4.6.6. Railing

1) All emergency exits must be protected on each side by a wall or railing securely installed.

2) Subject to paragraph 4), railings of emergency exit stairways must have a height of at least 920 mm measured vertically from the nosing of the stair to the top of the railing and at least 1070 mm on the edge of the landings.

3) Railings of emergency exit ramps and landings must have a height of at least 1070 mm measured vertically from the surface of the ramp to the top of the railing.

4) Railings for exterior stairways and landings located at more than 10 m above the adjoining ground must have a height of at least 1500 mm measured vertically from the surface of the landing or the nosing of the stair, up to the top of the railing.

5) Openwork parts on the railing of an emergency exit must not allow the entry of a spherical object of more than 100 mm in diameter, unless it can be proven that the openwork parts with dimensions exceeding this limit do not present any risk.

6) Windows in staircases with a support located at less than 900 mm in height in relation to the nosing of the stair or at a height of 1070 mm minimum in relation to the landing must:

a) be protected by a railing with a top section located:

i) at a height of about 900 mm in relation to a line connecting the nosing to the stairs; or

ii) at 1070 mm at least above the landing; or

b) be subject and designed to resist to specified lateral loads for railings and walls in articles 4.1.5.1.4.and 4.1.5.1.6.

7)Railings must be designed in a way that elements, supports or openings located between 140 and 900 mm above the level protected by these railings do not allow any climbing, unless it is proven that the position and dimension of openwork parts exceeding this limit do not present any risks.