NOTE TO HOLDERS OF THE INSERT DESIGN HANDBOOK (ESA PSS-03-1202 Issue 1)

In Section 2.1.2.2 of the Handbook, a set of diagrams is presented, in which the permissible static tensile and compressive loadings of inserts are plotted. It has now been established that errors exist in the plot descriptions and that some of the curves themselves are inaccurate as a result of computer software faults detected by the contractor responsible for generating them. In view of this, pages 83 to 274 of the Handbook are to be discarded.

The pages bearing the revised plots, plus a few others on which typographical errors have been detected, constitute Issue 1 Revision 1 (September 1990) of the Insert Design Handbook and are now sent to all holders under cover of this note.

ESA PSS-03-1202 Issue 1
June 1987

Insert Design Handbook

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ABSTRACT

The large variety of existing insert systems presents the designer a confusing picture. The aim of the present handbook is to assist the designer by presenting him in a single document with all the information relevant to the design, manufacturing and verification of insert systems and by limiting consideration to a restricted number of standard dimensions.

The matter presented in the document was compiled during a program performed under contract by ERNO (reported in ESA Contract Reports ESA CR(P)-1498 (February 1981) and ESA CR(P)-1665 (December 1981)).

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REVISION PROCEDURE

Revisions to the Design Handbook may be of three kinds:

1) Textual changes necessitating the replacement of pages
2) Additions requiring the introduction of new pages
3) Additions requiring the introduction of new sections.

Each change is indicated by a running index letter following the page number. If new (additional) pages are introduced, they are indicated by a numerical index preceding the letter index. For example:

Case 1 : Old page 183 is replaced by new page 183a.

Cases 2 and 3: New (additional) page 183.1a is inserted after page 183;
new (additional) pages 94.2.1b, 94.2.2b and 94.2.3b are inserted after page 94.2a.

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INTRODUCTION

i. Scope

In view of the variety of existing design methodologies related to insert systems this handbook has been prepared in an attempt

- o to collect all information relevant to the design, manufacturing and verification of insert systems into a single reference document, and
- o to provide a standardisation procedure for the designing analysis and testing of inserts.

ii. Source of Material

The information presented is the result of a standardisation program performed by ERNO under ESA Contract No. 3442/77/NL/PP which is reported in ESA CR(P)-1498 and ESA CR(P)-1665.

iii. Approach

The arrangement of the material contained in this handbook follows the usual development sequence of an insert system.

In section 1 the designer is made familiar with the specific features of the components making up an insert system (insert, sandwich, means of attachment). An approach to the design of insert systems is recommended. Static insert load- carrying capabilities are compiled in section 2, together with a short description of the related stress situation and the associated failure mechanisms. Consideration is given to the various possible loading conditions (tension, compression, shear, etc.) and to those effects that reduce the basic static load-carrying capabilities (mutual interference of inserts, panel-edge influences, environmental influences, and cyclic loading fatigue).

Insert system manufacturing is covered in section 3.

The criteria related to insert system design verification, i.e. testing and quality assurance, are described in section 4 and section 5, respectively. The detailed analytical determination of the static load-carrying capability of an insert is outlined in Appendix A.

NOMENCLATURE

a	insert distance
av	average value
b_i	insert radius
b_p	potting radius
b_{pmin}	minimum potting radius
b_{ptyp}	average or typical potting radius
b_R	real potting radius
b_{Rtyp}	average or typical real potting radius
c	core height
d_i	insert diameter
d_p	potting diameter
e	insert's distance from the sandwich panel edge
f	facing sheet thickness when $f_1 = f_2$
f_1	thickness of upper facing sheet
f_2	thickness of lower facing sheet
guar	guaranteed value
h_i	insert height
h_p	potting height
h_{pmin}	minimum allowable potting height
h_{ptyp}	typical potting height
min	minimum value

n	number of inserts in an insert group
t_o	core foil thickness
typ	typical value
x	distance between facing sheet upper surface and insert upper flange surface

A	one sixth of hexagonal cell circumference
AA	American Aluminium Association
B	bending stiffness
C'	correction factor for strength capabilities with heights of core > 9 mm
D	foot diameter of an attached structural part
E	Young's modulus
E_f	Young's modulus of isotropic face sheet material
E_{xy}	Young's modulus of anisotropic face sheet material
E_R	tensile modulus of potting compound
F	applied inclined load
F_{SS}	static strength capability under loads inclined to plane of facing
G_C	effective core shear modulus
G_L	shear modulus of core in L-direction
G_W	shear modulus of core in W-direction
K_t	magnification factor due to fatigue
K_{tpp}	stress concentration factor due to partially potted inserts in non-metallic cores
L	longitudinal direction of a honeycomb core
LN	Luftfahrt-Norm (aeronautical standard)
M	bending moment
M_{SS}	allowable bending moment related to static insert strength

N	newton
N_{pc}	number of core cells filled with potting resin
P	load normal to plane of facing
$P_{crit\ min}$	insert load capability due to minimum properties of the components (core, facing, resin)
$P_{crit\ typ}$	insert load capability due to the typical properties of the components
P_{SS}	static strength capability of an insert under loads normal to plane
P^*_{SS}	reduced static strength capability of an insert due to edge effects
$P_{SSc\ min}$	minimum insert load carrying capability in compression
$P_{sst\ av}$	average insert load carrying capability in tension
$P_{sst\ min}$	minimum insert load carrying capability in tension
Q	resulting shear load
Q_c	portion of Q taken by the core
Q_{SS}	allowable shear load
Q^*_{SS}	reduced shear load for inserts near panel edges
R	rear stress rate
RC	reliability coefficient
RT	room temperature
S_c	core cell size
T_{ss}	allowable torsional load
W	transverse direction of a honeycomb core

α	angle between insert load direction and facing plane
γ_c	density of the expanded core
γ_o	density of the material
γ_R	density of the potting resin
η_{EN}	edge coefficient of inserts loaded in tension or compression
η_{EQ}	edge coefficient of shear loaded inserts
ηh_G	interference coefficient of a group of equidistant inserts
η_{IC}	interference coefficient of inserts loaded in opposite directions
η_{IS}	interference coefficient of two neighbouring inserts
η_{IS1}	load capability reduction coefficient of two neighbouring inserts
η_T	coefficient of thermal degradation
η_{TA}	load capability reduction coefficient of insert exposed to elevated temperature
η_{TC}	load capability reduction coefficient of inserts exposed to thermal cycling
η_{Tb}	load capability reduction coefficient of insert at RT after 20 hours exposure to elevated temperature
η_{TR}	reduction coefficient of potting resin strength at elevated temperatures
ν_f	Poisson's ratio of isotropic facing sheet material
$\nu_{x,y}$	Poisson's ratio of anisotropic facing sheet material
$\sigma_{c\ crit\ c}$	core strength in compression
$\sigma_{c\ crit\ t}$	core strength in tension
$\sigma_{c\ crit\ c\ min}$	minimum compression strength of core
$\sigma_{c\ crit\ c\ typ}$	typical compression strength of core
σ_{fy}	yield strength of facing sheet material
$\sigma_{R\ crit}$	tensile strength of potting resin

$\tau_{c\ crit}$	core shear strength effective to insert strength (circular)
$\tau_{c\ crit\ min}$	minimum allowable core shear strength
$\tau_{c\ crit\ typ}$	typical or average core shear strength
τ_{Lcrit}	critical shear strength of core in L-direction
τ_{Rcrit}	shear strength of potting resin
τ_{Wcrit}	critical shear strength of core in W-direction

LIST OF REFERENCES

[1] Standardization of Design Analysis and Testing of Inserts in Structural Sandwich Elements, Final Report (3442/77/NL/PP)

[2] Standardization of Design Analysis and Testing of Inserts in Structural Sandwich Elements, Final Report of Rider I (3442/77/NL/PP)

[3] Standardization of Design Analysis and Testing of Inserts in Non-Metallic Structural Sandwich Elements, Phase I Report (440/80/NL/AK(SC))

[4] MIL-Handbook 23B

[5] MIL-Std-C-7438

[6] W.S. Ericksen:
The Bending of a Circular Sandwich Plate Under Normal Load,
Forest Products Laboratory, Report No. 1828, Madison 5, Wisconsin, 1953

[7] W.G. Youngquist/E.W. Kuenzi:
Stresses Included in a Sandwich Panel by Load Applied at an Insert,
Forest Products Laboratory, Report No. 1845, Madison 5, Wisconsin, 1955

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DOCUMENT CHANGE RECORD
INSERT DESIGN HANDBOOK
(ESA PSS-03-1202 Issue 1)

Issue/Rev. no.	Page(s)affected	Remarks
Issue 1/Rev 1	28 and 29	Tables 1.2.7.1 and 1.2.7.2 amended
	37	Equation 1.2.7.a amended
	38	Caption of Fig. 1.2.11 amended
	63 and 64	Edited and reset and note added
	66	Tensile strength values amended
	68	Table 2.1.1 amended
	75	Wording of Para. 4 of Section 2.1.1.2 amended
	83-274	Corrected curves
	289	Equation 2.2.3 amended
	371	Equation 1.1 amended
	373	Changes in definitions of I_m, α and $\tau(r)$
	374	Change in definition of $\tau(r)$
	375	Correction of Eq. (1.16) and preceding line
	376	Several small corrections
	377	Several small corrections
	379	Correction of Eqs. (1.17) to (1.24)
	380	Whole page revised
	381	Two small corrections
	382	Word 'compressive' italicised
	385 and 386	Headings a) and b) amended

ISSUE STATUS SHEET
INSERT DESIGN HANDBOOK
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Section	Page(s)	Issue/Rev	Section	Page(s)	Issue/Rev
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			Section 4	351-356	1/0
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	75	1/1			
	76-82	1/0	Appendix B	387-398	1/0
	83-274	1/1			
	275-288	1/0			
	289	1/1			
	290-330	1/0			

1.0 DESIGN

1.1 Definition of the Insert System

The insert is part of a detachable fixation device. It permits the interconnection of honeycomb-sandwich structures, the connection between such structures and other structural parts (frames, profiles, brackets) and the mounting of equipment (boxes, feed lines, cable ducts, etc.).

The system consists of a removable and a fixed structural element. The removable part is either a screw or other threaded element adapted to a nut-like part, the insert. This is connected to the honeycomb-structure by means of an epoxy compound.

The insert system as considered here consists of three main components:

- o Insert
- o Sandwich structure
- o Potting material

The following sections give a description of the components and their relation within the system.

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1.2 Definition of Insert System Components

The components forming the insert system are summarised in Tab. 1.2.1.

1.2.1 Insert

1.2.1.1 Types

There are three types of insert which are distinguished by the method of integration into the honeycomb sandwich structure:

(A) by simultaneous bonding during sandwich production

(B) by potting with a curing resin into an existing sandwich

(C) by mechanical clamping or screwing into an existing sandwich (see also Tab. 1.2.3)

The inserts grouped in (A) are used only in rather thin sandwich structures (i.e., with small core height) and can be applied only in cases where no particular locking requirements exist. Moreover, it is rather difficult to position the insert exactly at the point at which it is required for connection purposes. For this reason, the insert must have a large diameter to allow the drilling of a bore hole and cutting thread within a margin of 3 - 6 mm to allow for misalignment.

The mechanically fastened inserts in group (C) have significant disadvantages:

- o No direct connection with the sandwich core which causes low load-carrying capability.
- o An individual adapted size for each core height.
- o Torque can be transferred by adhesive bonding only.

Group (B), inserts potted by means of curing epoxy resin, is the most important group. The present handbook is concerned exclusively with inserts of this type.

This type of insert, incorporated in honeycomb-sandwich structures by potting, has the basic shape shown in Fig. 1.2.1.

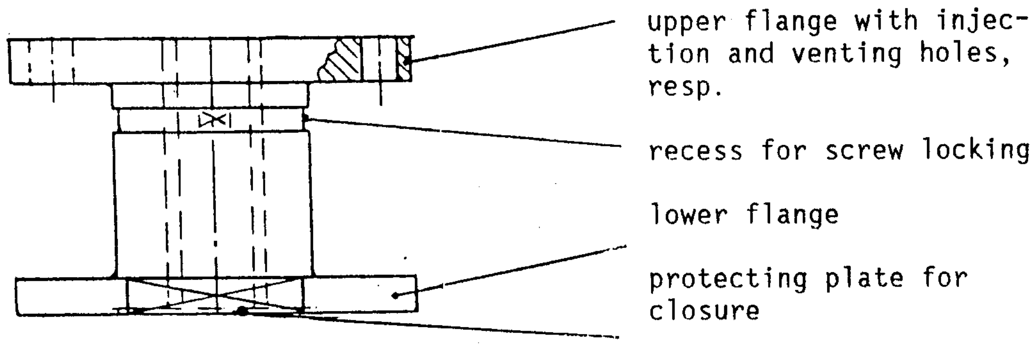


Fig. 1.2.1:
Typical Insert

A hollow cylindrical body with flanged ends is the standard configuration. Both the discs or flanges provide a form-locking connection with the resin and prevent applied loads from being transferred only by adhesion shear forces between resin and insert. The upper flange is pierced by two bore holes, one for the injection of the potting resin and one for venting purposes. The cylindrical section and the lower flange have a riffled surface or the lower flange is faced on two opposite sides. Both provisions increase the shear load capability when the insert is subjected to torsion. A thin circular sheet in the lower flange protects the thread from resin contamination during potting. A recess in the upper part of the cylindrical body permits thread deformation by compression. This is to ensure self-locking of the mated screw.

INSERT SYSTEM

Insert		Joining means			Sandwich		
Male threaded element	Female threaded element (either fixed or exchange-able)	Mechanical clamping or screwing	or Bonding with resin: Simul-taneously during Sandwich Production.	or Integration into existing Sandwich (Potting)	Facing Sheet	Bonding Component	Core
See Sect. 1.1 Table 1.2.3		not recommended	Table 1.2.3	See Sect. 1 and 3	See Sect. 1.2.2		

Table 1.2.1: General Definition of Insert System

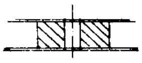
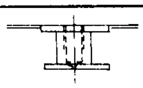
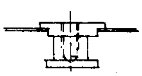
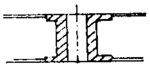
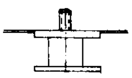
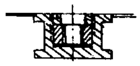
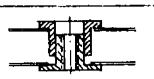
Four different methods of potting the inserts are in general use, as described in Tab. 1.2.2, of these, the injection method is the most frequently employed, because of its advantages especially when a large number of inserts have to be fitted.

The data presented in section 2 are based upon test results from specimens prepared by the injection method in accordance to the manufacturing procedure, section 3.2. If other techniques are used, the potting dimensions need to be justified.

Method of Potting	Device	Grade of Potting	Certainty in Attending the Expected Filling	Remarks
casting	Resin funnel apparatus	full	very good	Feasible but unpracticable method, requires a resin reservoir above each insert to complete the filling during shrinking of the resin
		partial	bad	Sandwich plate must be turned over before curing (no longer in use)
injection	Compressed air cartridges (Semco cartridges)	full * partial	good * good	Very economical method when a great number of inserts is to be placed
	hand inject. with little medical squirt	full * partial	good * good	Usual when a small number of inserts is employed (Repair etc.) Injection methods allow handling of sandwich plate immediately after potting
foaming	no	full	good	Usual when inserts have to be potted during sandwich manufacture process.
paste application	spatula	full partial	bad	not to recommend

* 100 % filling is not possible because a small amount of air will always be enclosed on the top of core cells.

Table 1.2.2:
Potting Methods

	Type	Fastening Principle	Shape	Diameter (mm)	Material	Potting Conditions	Torque Locking	Thread Locking	Floating Nuts Exchanging Capability	Standards	Remarks
(A)	1	Bonding during sandwich production		17 – 30	Al	full bonded with core filler	no torque locking or square shape	Loctite etc.	no no		The bore hole will be drilled after sandwich bonding. Only for small core height.
	2			11 – 22	Al (St) (Ti)	partly or fully potted		Deformation of Thread	no	NAS 1832 NSA 5136 PA 3825 ENN 366/386	The Al insert can be supplemented by St or Ti screws. Mostly applied type.
	3			11 – 12	Al (St) (Ti)	partly or fully potted		Deformation of Thread	no no		Rare Application
	4			11 – 14	Al	only fully potted		Loctite etc.	no no	NAS 1832 TAN 16489 PAN 3827 NSA 5071	Available with and without thread
* (B)	5	Potting		6 – 14	St Ti	partly or fully potted	planes or riffles	Loctite etc.	no no	ERNO – No. R 000/095-000	Rare Application
	6			3 – 6	St Ti	partly or fully potted		Loctite etc.	no no		Only for very low load. Rare Application
	7			19 – 70	Al	partly or fully potted		Loctite etc.	no no		for max. loads.
	8			19 – 25	Al-Insert Ti-Nut	partly or fully potted		Deformation of thread	yes yes	NAS 1835 PAN 3829 ENN 379 TAN 16488 NSA 5072	Extended and heavy type for applying floating nuts and exchanging capability
(C)	9			14 – 22	Al (St) (Ti)			Deformation of thread	no no	TAN 16485	Low pull out strength if there is no connection to core.
	10	Mechanically clamped or screwed		14 – 22	Al (St) (Ti)		adhesive bonding		no no		

*) exclusively considered in this Handbook (Sect. 1.2.1.1)

Table 1.2.3: Types of Inserts

1.2.1.2 Sizes of Inserts

Since inserts have been developed separately in various countries by different companies, there is a broad variety of sizes, shapes and dimensions. Most of these inserts have been qualified to meet company standards, project-related standards or, after approval by national airworthiness authorities, national standards. A probably incomplete list of standards is given in Tab. 1.2.4.

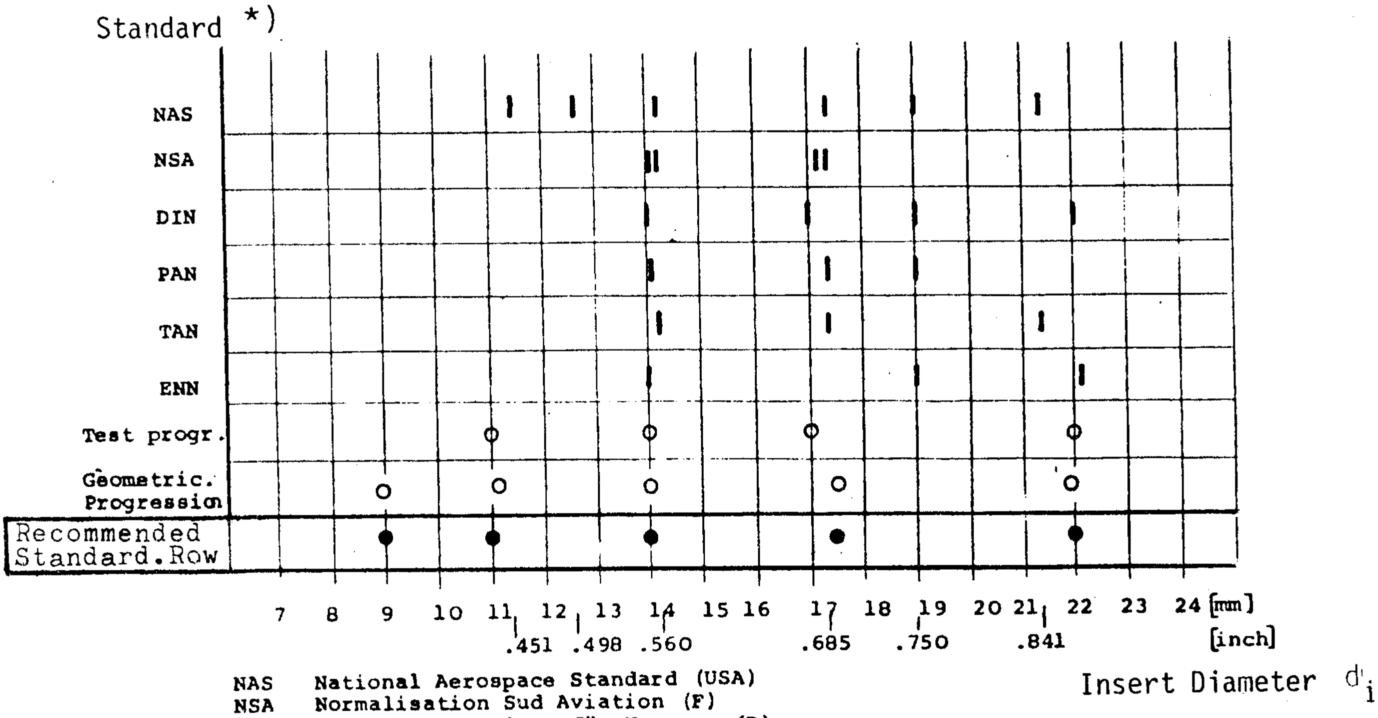
The most important parameters related to strength are the two dimensions

- o insert overall diameter d_i
- o insert overall height h_i

Consequently, in this handbook, the insert load-carrying capabilities are based on these two parameters.

The standardised diameters are listed in Fig. 1.2.2, which shows that certain diameters are preferred. The line "Test progr." denotes the diameters which have been investigated within the test program, see Ref. [1]. The subsequent line indicates the diameters which follow a geometrical progression of the type $a.q^n$ in which the constants are $a = 8.96$ and $q = 1.25$. The last line indicates the recommended standard set of diameters, which best fits the presently standardised diameters.

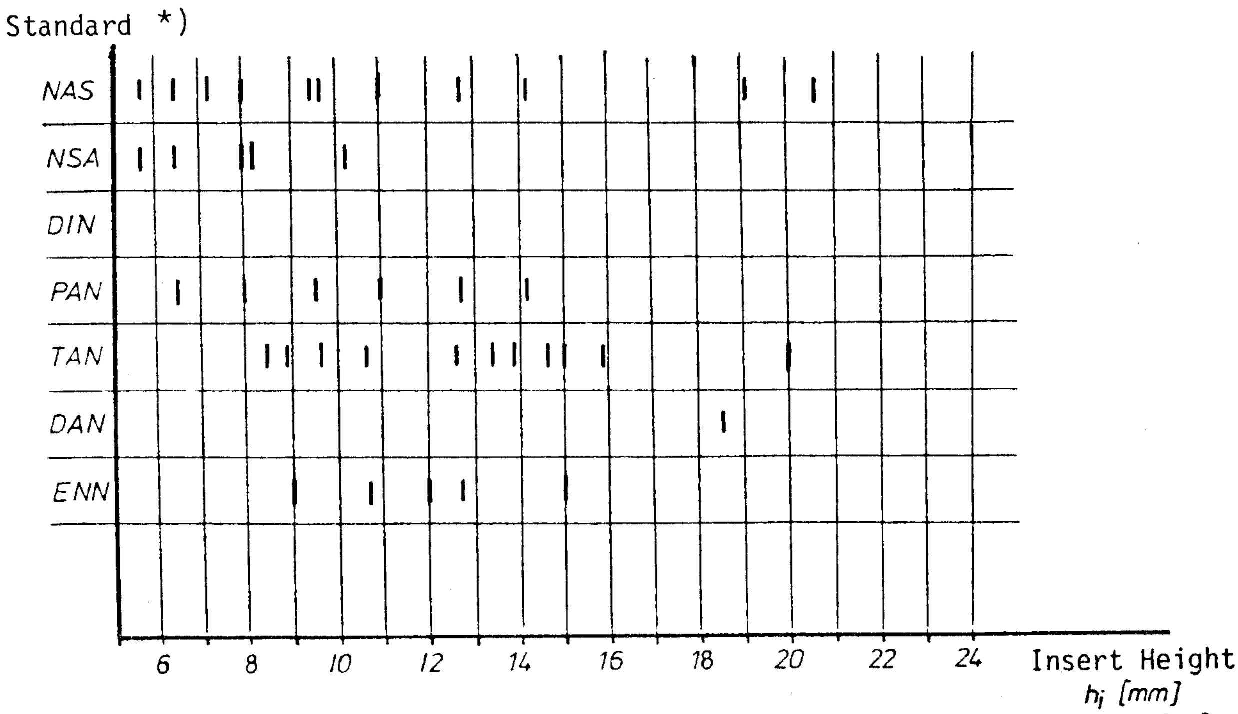
The standardised insert heights in Fig. 1.2.3 show considerable scatter and no definite tendency of preferred heights can be identified. However, if standardised insert heights are plotted as a function of standardised insert diameters (Fig. 1.2.4), the dashed lines denote examples of linear dependencies. On the basis of the straight line which connects the crossing of preferred diameters with heights in whole millimetres, a recommended set of insert heights has been derived.



NAS National Aerospace Standard (USA)
NSA Normalisation Sud Aviation (F)
DIN Deutsches Institut für Normung (D)
PAN Panavia Standard (D,I,UK)
TAN Transall Norm (D,F)
ENN ERNO Norm (D)

*) see Table 1.2.3

Fig. 1.2.2: Standardized Insert Diameter



*) See Table 1.2.3

Fig. 1.2.3: Standardized Insert Height

National Aerospace Standard:	NAS	1832 1833 1835 1836 1837
Deutsches Institut für Normung	DIN	65187 65188 65189 65190 65191 65192 65193
Transall-Norm:	TAN	16487 16488 16489 16490
Panavia-Standard	PAN	3825 3826 3827 3828 3829
Deutsche Airbus-Norm:	DAN	214
Normalisation Sud Aviation:	NSA	5345 5074
ERNO-Norm:	ENN	366 377 379 386 398

Table 1.2.4: List of Standards

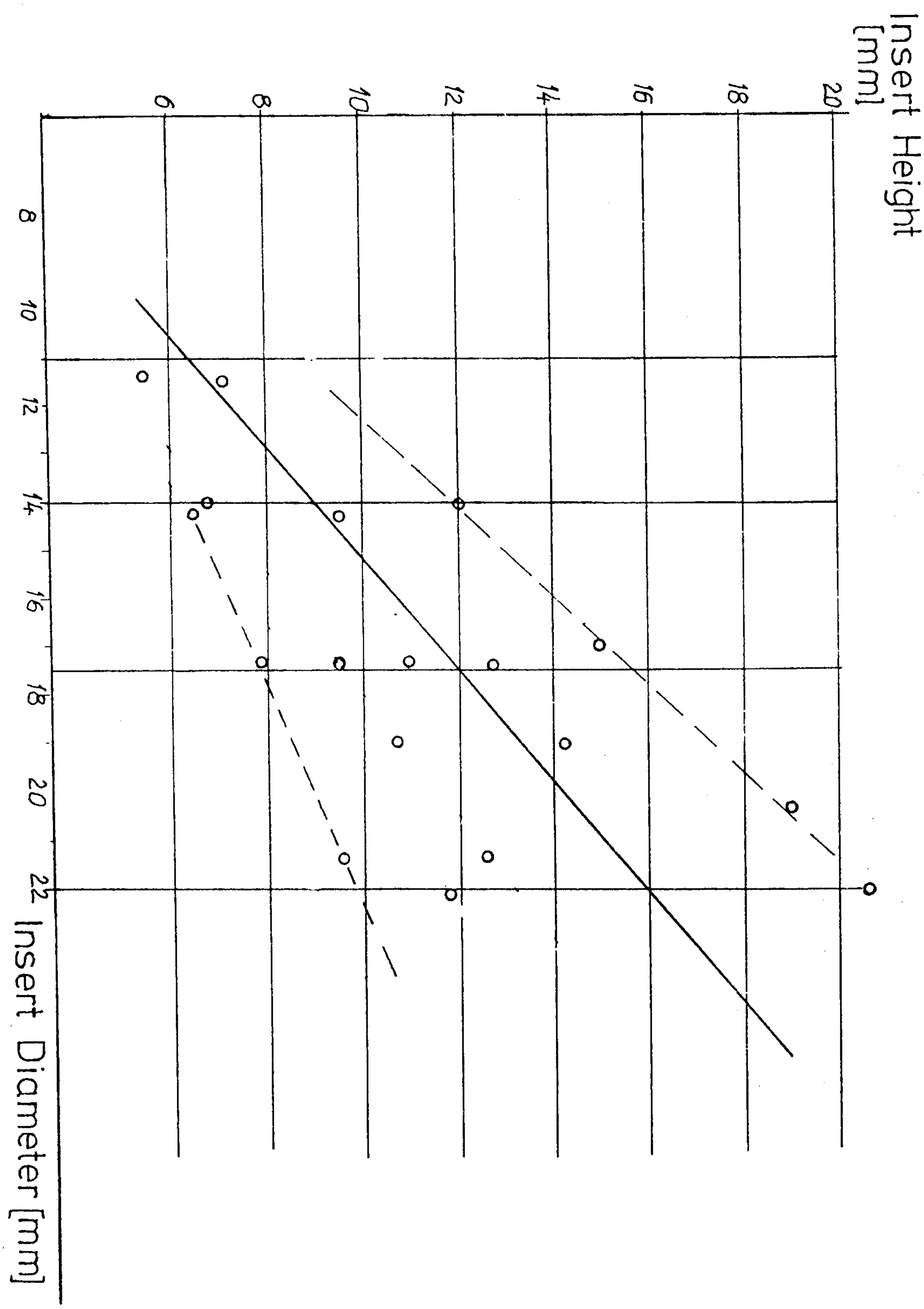


Fig. 1.2.4: Preferred Row of Insert Height

1.2.1.3 Insert Materials

Usually inserts are made of aluminium alloy AlCuMg2, solution heat treated and naturally or artificially aged, thus having the condition T85. The comparable material designations are:

o	in Germany	3.1354-T851	Werkstoff-Leistungsblatt
o	in U.S.A.	QQ-A-225/6-T8511 (2024-T8511)	Federal Specification (MIL-HDBK-5D)
o	in the U.K.	3L65	BS
o	in France	A-U4G1	Air 9050/C
o	in Italy	PAC 4,5 GM	UNAVIA 811-02

(See Tab. 1.2.5.)

For applications where improved strength or special locking properties are required, titanium alloy TiAl6V4 solution, treated and aged, is in use. Steel is also sometimes used, e.g. carbon steel AISI 1137 (as referred in Fed. Std. 66) in a heat-treated and water-quenched condition. Inserts made from carbon steels are always cadmium plated. Their use in spacecraft structures is not allowed, owing to sublimation problems that may arise in thermal vacuum. In this case, carbon steels are replaced by stainless steels of the austenitic type, e.g. AISI 303 or 1.4305 according to DIN 17007.

The use of materials which offer a better temperature resistance than aluminium provides no advantage if the insert is potted with an epoxy resin, i.e. the resin will fail at temperatures much lower than ones harming the insert.

It is also unreasonable to select an insert material stronger than aluminium, since the strength of the system is restricted by the strength of the epoxy.

Inserts with changeable floating nuts make it possible to apply a material of greater strength for the nut operating in the aluminium housing.

In case of passing screw thread the bore with the internal thread is closed on the bottom side of the lower flange by a thin flat shim or cup made of aluminium alloy AlMgSiCu, i.e. AA 6061 in a soft annealed temper.

1.2.1.4 Surface Protection of Inserts

All inserts require a surface protection to prevent corrosion. The housings made from aluminium alloy AlCuMg2 are treated by an anodising process, as specified for instance in LN 9368, Code No. 2100 or MIL-A-8625 C.

Galvanic treatment in a sulphuric-acid bath generates a 10 to 15 µm thick aluminium oxide layer which is hard, is electrically nonconductive and preserves the insert from corrosive attack, while providing suitable bonding conditions.

Housing, plug and nut of inserts with floating and removable nuts are treated in the same manner. Covers closing the bore hole are chromated in accordance with MIL-C-5541, Class 1A. When a cup is applied as a closure, the inner and outer surfaces are chromated. Inserts of stainless steel are passivated according to LN 9368, Code No. 1200.

Titanium parts, if any, are used without any treatment because they automatically develop a protective oxide layer after machining. In order to increase protection against corrosion, an additional coating may be created by an anodising treatment (acc. to LN 9368, Code No. 2500).

INSERT MATERIALS		APPLIED SURFACE PROTECTION	CHARACTERISTIC PROPERTIES
DESIGNATION	APPLICABLE SPECIFICATIONS		
AlCuMg2 heat-treated and aged (naturally or artificially); Condition T85	o 3.1354 - T8511 Werkstoff-Leistungsblatt o 2024 - T8511 QQ-A-225/6 o 811-02 UNAVIA o A-U4G1 AIR 9050	Anodized (e.g. LN 9368 Code 2102 MIL-A-8625C)	
TiAl6V4 solution treated and aged	o 3.7164.7 Werkstoff-Leistungsblatt o Ti-6Al-4V MIL-HSBK-5D o COMP.T-A6V AIR 9183	Normally not necessary; for special cases anodized	
Carbon Steel	o AISI 1137	Cadmium plated	Not allowed in spacecraft structures owing to sublimation problems
Stainless Steel	o AISI 303 ASTM A 582 o 1.4305 DIN o 303 BS	Passivated LN 9368	
AlMgSiCu soft annealed temper	o AA 606 o 3.3214 LN o 811-05 UNAVIA	Chromated	

Table 1.2.5: Compilation of Typical Insert Materials

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1.2.2 Definition of Sandwich

This section deals only with those properties of the sandwich that are relevant to the inserts' load capability.

The sandwich consists of the following parts:

- o Facing sheets
- o Core
- o Adhesive film for bonding

The contribution of these parts to the inserts' load capability is shown in Tab. 1.2.6.

Load Type	Contribution of Sandwich Component to Inserts' Load Capability		
	Core	Facing Sheet	Core/Facing Bonding
Tension	major	medium	very little*
Compression	major	medium	little
Shear	little	major	very little*
Bending	major	medium	little
Torsion	major	little	little

* Influence in case of non-metallic facings may need reconsideration.

Tab. 1.2.6: Influence of Sandwich Components on Insert Capability

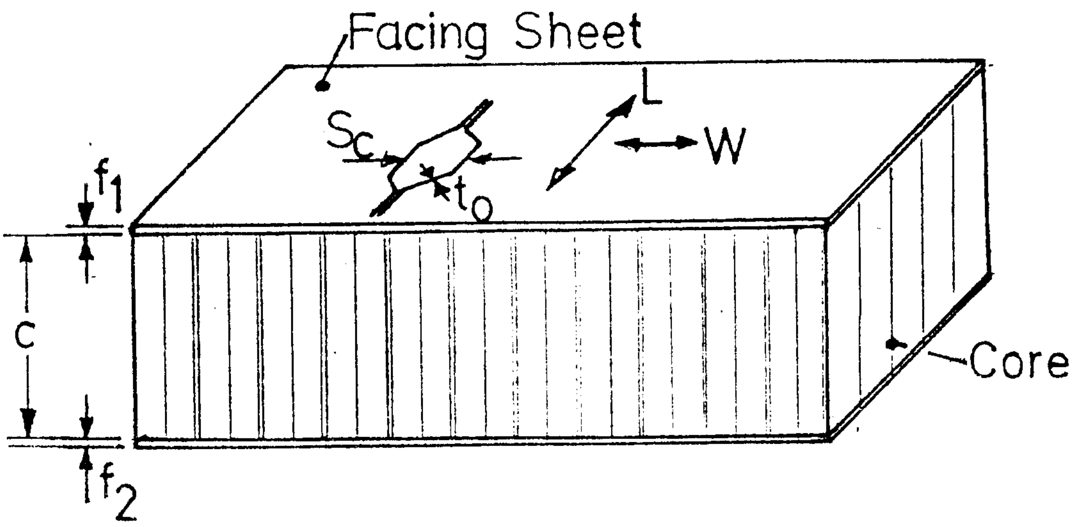

Fig. 1.2.5: Designations of Sandwich and Core

The principal dimensions of a sandwich are (Fig. 1.2.5)

f_1, f_2 = thickness of facing sheets, f if $f_1 = f_2$

c = core height

1.2.2.1 Facing Sheet Properties

a) Tensile and Compressive Loading

The insert's capability under tensile and compressive loading is influenced by the bending stiffness B of the facing sheets. The higher the bending stiffness of the facings compared with the shear stiffness of core, the higher the load contribution of the facing sheets.

$$B = \frac{E_f \, f^3}{12\,(1-\nu_f^2)} \qquad \text{for isotropic facings} \qquad (1.2.1)$$

Thus the relevant properties of the facings are

f = facing-sheet thickness
E_f = Young's modulus of facings
ν_f = Poisson's ratio of facings
σ_{f_y} = yield strength of facings

For an analytical determination of the insert load capability these values have to be applied in the equations developed in Appendix A.

For anisotropic facings, the coupling and flexural stiffness has to be used for the calculation of the load contribution of the facing sheets.

With respect to the slight influence of the facing of about 10 to 20 % at typical facing/core combinations, the following sufficient exact assessment can be done.

E_f and ν_f^2 in equation (1.2.1) are replaced $\sqrt{E_x \cdot E_y}$ and $\nu_x \cdot \nu_y$ respectively, where these values are results of the in-plane laminate theory.

The following conversion allows to use the insert capability diagrams, which are actually generated for sandwich structures with different aluminium facings, for sandwich structures with anisotropic facings, too.

The strength values of the facing sheets usually have no influence on the tensile or compressive load-carrying capability of an insert.

$$f_{Al} = f_{an} \sqrt[4]{\frac{\sqrt{E_x \cdot E_y} \cdot (1-\nu_{Al}^2)}{E_{Al}\,(1-\nu_x \cdot \nu_y)}}$$

with f_{Al} = facing thickness aluminium
f_{an} = facing thickness anisotropic material
E_x = E-modulus x-direction
E_y = E-modulus y-direction
ν_{Al} = Poisson's ratio aluminium
ν_x = Poisson's ratio x-direction anisotropic
ν_y = Poisson's ratio y-direction anisotropic

b) Shear Loading

For in-plane shear loads (see Fig. 1.2.18, mode c) of isotropic facings the yield strength of the upper facing sheet (section 1.2.2.2.4) is relevant to the insert load capability. The failure mode will be a compressive buckling of the isotropic facing.

An in-plane shear loaded anisotropic facing (e.g. CFRP) may fail by different modes (see Fig. 2.1.6).

Fig. 2.1.7 gives the shear load capabilities of tested CFRP facings manufactured from two materials often used in spacecraft.

At deviations in material or stacking sequence of the composite facing the ennumbered shear load capabilities can only be a gross due for the designer. In this case detailed investigations of the pin loaded shear capability of the selected composite have to be performed.

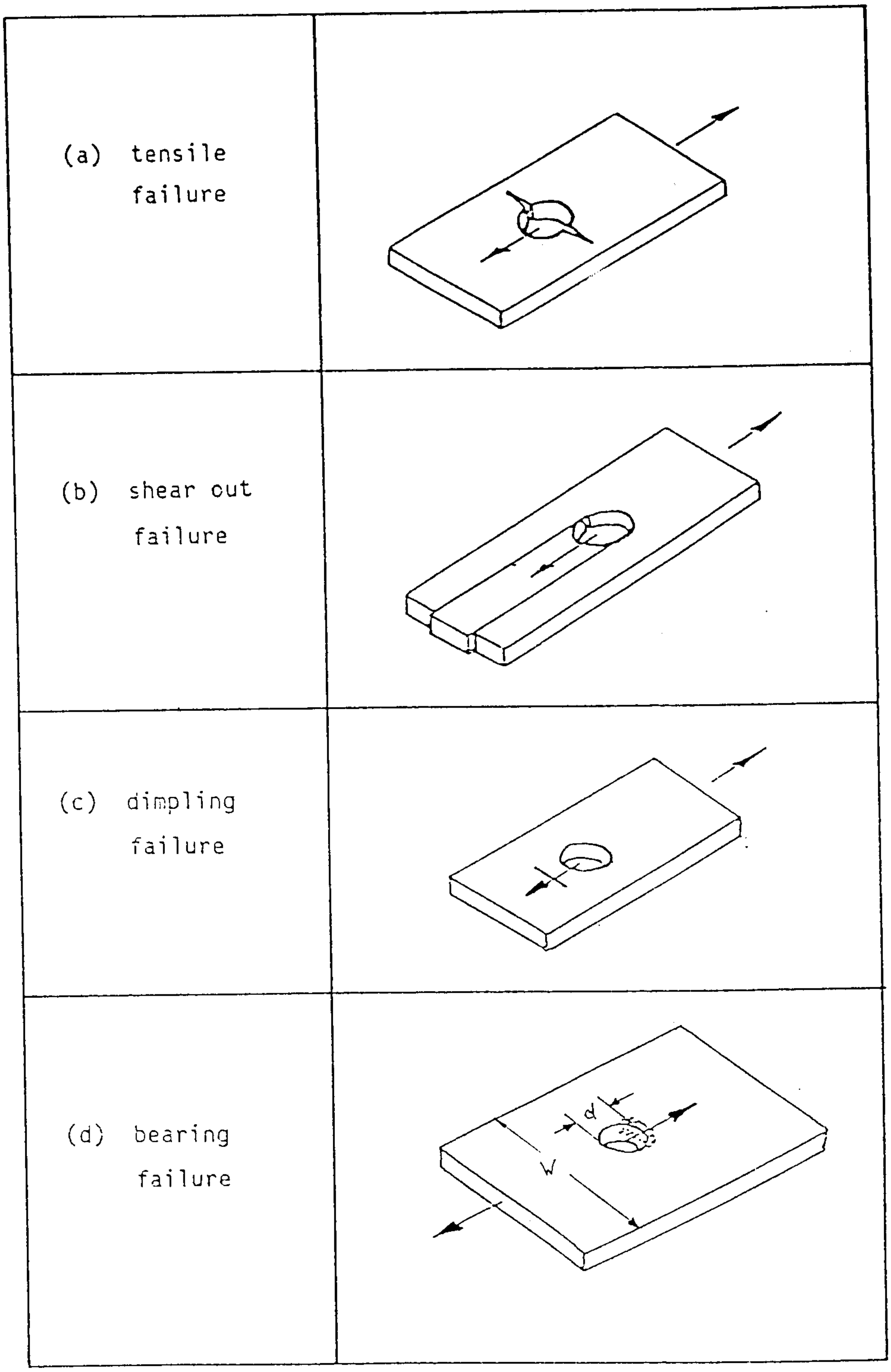

Fig. 1.2.6: Possible Failures Modes of Anisotropic Facing Sheet Loaded by Shear Loads

Laminate	Fibre Orientation outer fibre / inner fibre	E^{0^o} basis test / E^{0^o} theor. * (N/mm²)	σ^{0^o} max, basic test / σ^{0^o} theor. * (N/mm²)	$P_{max, test}$ (N)	failure modes	tension compression	d_{ins}** / w
914 C – T300	0/90	75,047	812 790	2653 2760	dimpling dimpling	T C	0,25
	90/0	75,047	812 790	2253 2160	dimpling dimpling	T C	
	45/–45	13,086	151 228	2660 2381	bearing dimpling	T C	
	45/0/–45	57,714	645 602	4653 4163	bearing bearing	T C	
	22.5/–22.5/–67.5	37,610	319 380	4531 4315	bearing bearing	T C	
	60/0/–60	52,631	568 589	3870 3813	bearing bearing	T C	
	30/–30/–90	27,344	216 293	3605 3858	bearing bearing	T C	
914 C – HM	0/90	95,542	545 410	1825 2128	tensile dimpling	T C	
	45/–45	12,518	80 118	1931 2069	tensile	T C	
914 C – T300	45/–45	13,086	151 228	2234 1849	bearing tensile bearing tensile	T C	0,16

*The underlined properties determined by laminate theory
**Insert Diameter/Specimen width

Fig. 1.2.7: Failure Mode and Shear Load Capability of Tested CFRP Facings

c) Other Loadings

No significant impact of facing sheet properties on other loadings is expected.

1.2.2.2 Core Properties

1.2.2.2.1 General Remarks

This Design Handbook is primarily restricted to hexagonal honeycomb cores, although the analytical determination of the insert load capability as described in Appendix A is also valid for other types of core, i.e. tubular, corrugated and foam cores.

The relevant dimensions of the hexagonal core are (see Fig. 1.2.5):

- o Cell size S_c
- o Foil thickness t_o

Two principal directions characterise any hexagonal core:

- o the L-direction, coinciding with the direction of the doubled foils
- o the W-direction, perpendicular to the L-direction

Resulting from this core anisotropy, the shear strength and the shear modulus in L-direction are approximately twice those of the W-direction. This anisotropic behaviour has only a small influence on the insert strength capability.

Owing to

- o deviations in the nominal core density (± 10 %) caused by:
  - deviations in the nominal foil thickness
  - deviations in geometrically exact hexagonal cell forms caused by the expansion process

- o prebuckling properties of the cell walls caused by the hole piercing process on perforated cores

the mechanical properties of cores vary very widely, as shown in Fig. 1.2.8 and section 1.2.2.2.4.

Consequently, a distinction is made between:

- o guaranteed core strength related to minimum insert load-carrying capabilities combined with minimum potting size;

- o typical core strength related to typical insert load-carrying capabilities combined with typical potting size.

The core properties are most important for inserts subjected to normally acting tensile or compression loads. These properties are

- o the shear modulus
- o the shear strength
- o the tensile strength perpendicular to the sandwich plane
- o the compressive strength perpendicular to the sandwich plane

They are compiled in Tab. 1.2.7.1 for common used types of aluminium cores and in Tab. 1.2.7.2 for common used types of non-metallic cores.

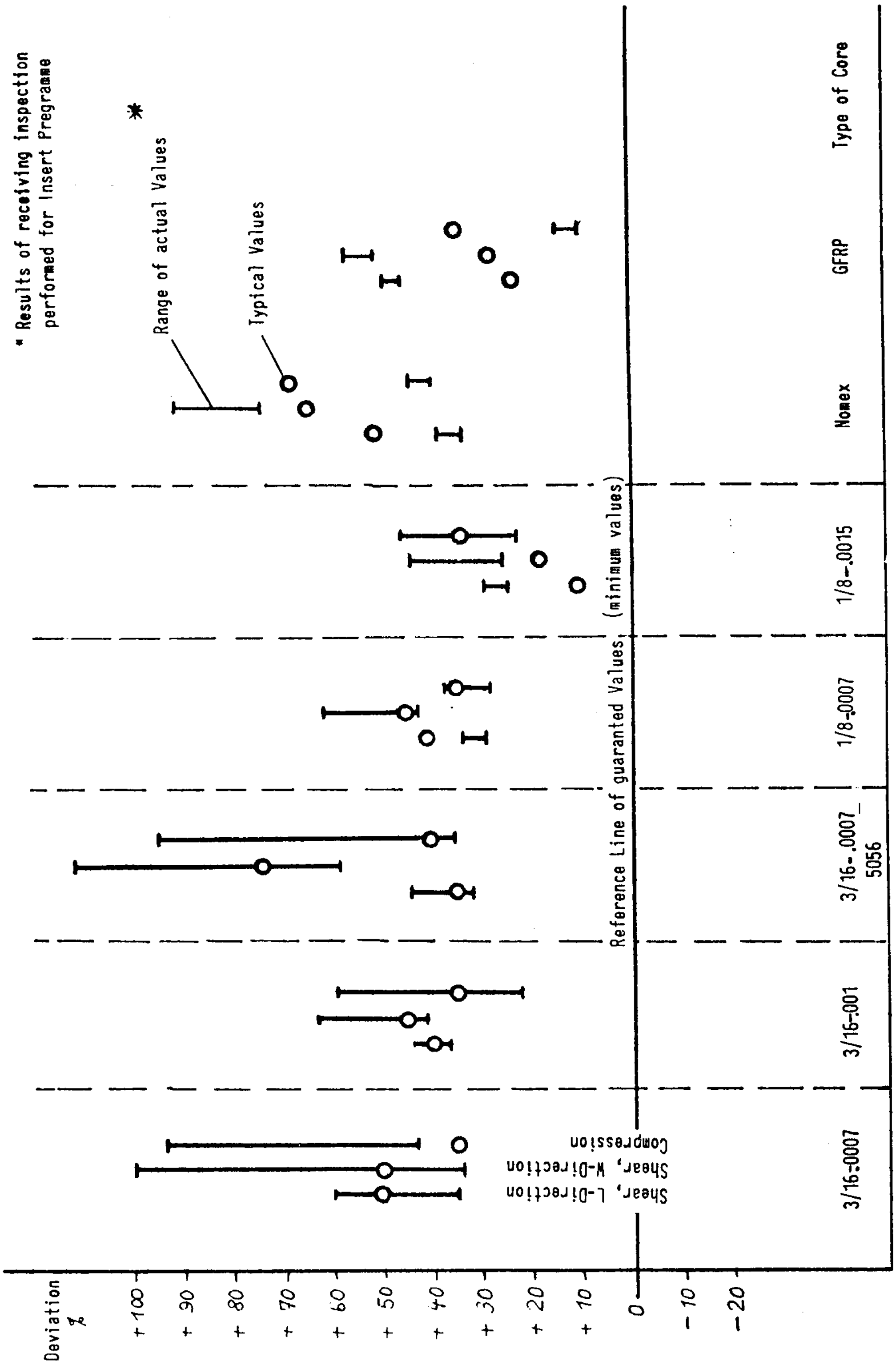

Fig. 1.2.8: Percentual Deviation of Actual Core Strength from Guaranteed Values

No.	Investigated Core Types	
	Core Designation*)	Material
1	3/16-5052-.0007	Aluminium Alloy
2	3/16-5052-.001	
3	1/8 -5052-.0007	
4	1/8 -5052-.001	
5	3/16-5056-.0007	
6	3/16-5056-.001	
7	1/8 -5056-.0007	
8	1/8 -5056-.001	
9	HRH10-3/16-2.0	Nylon fiber/ phenol resin (NOMEX)
10	HRH10-3/16-3.0	
11	HRH10-3/16-4.0	
12	HRH10-1/8 -1.8	
13	HRH10-1/8 -3.0	
14	HRH10-1/8 -4.0	
15	HRP - 3/16-4.0	GFRP
16	HRP - 3/16-5.5	

*) used designation key:

1 - 8: cell size - core alloy - foil thickness

9 - 16: material - cell size - density

Fig. 1.2.9: Core Designation Key

1.2.2.2.2 Shear Modulus of Core

The shear modulus of the core influences the way in which the load transmitted through the insert is distributed between facing sheets and core. The greater the core stiffness, the lower the load contribution of the facings.

Values of core shear modulus are not specified in standards such as MIL-C-7438 F. They are quoted only in data sheets prepared by core suppliers taking into account both core directions W and L. These figures are too high in comparison with insert test results and for this reason they cannot be applied for the analytical determination of the static strength of the insert.

The shear modulus is measured as varying with the loading and to decrease as a result of nonlinearity, i.e. shear buckling of single foils occurs at half its initial value. Consequently, an effective core shear modulus G_c is created which reflects the real situation

$$G_c = G_W/3 \qquad (1.2.2)$$

with G_W = shear modulus in W-direction.

Values of G_c are given in Tab. 1.2.7.1/2 for frequently used core types.

1.2.2.2.3 Shear Strength of Core

When inserts are subjected to tensile or compressive loads, the load-carrying capability is determined by the ability of the core to take the axially induced load transmitted from the insert via the potting resin. This can only be performed by shear forces.

When loaded in tension or compression, the insert system fails by a shear rupture of the core foils surrounding the insert. Because both foil directions participate in the transmission of the shear force, the circular strength is to be applied.

Designation*	Properties taken from supplier's data sheet	Properties determined by test**	Density	Cell size	Foil thickness	Shear modulus			Shear strength			Perpend. strength Tensile	Perpend. strength Compr.
			γ_c kg/m^3	S_c mm	t_o mm	G_L N/mm^2	G_W N/mm^2	G_C N/mm^2	τ_{Lcrit} N/mm^2	τ_{Wcrit} N/mm^2	τ_{Ccrit} N/mm^2	$\sigma_{Ccrit\ t}$ N/mm^2	$\sigma_{Ccrit\ c}$ N/mm^2
3/16 – 5052 – .0007p	guar typ	min av	28.8 32.0	4.8	0.02	186	98	32.6	0.55 0.83	0.32 0.48	0.44 0.65 0.57 0.73	2.77 3.08	0.69 0.93 0.77 0.93
3/16 – 5052 – .001p	guar typ	min av	44.7 49.7	4.8	0.03	310	152	50.6	1.07 1.45	0.62 0.90	0.84 1.22 1.08 1.28	4.31 4.79	1.48 2.00 1.69 2.00
1/8 – 5052 – .0007p	guar typ	min av	44.7 49.7	3.2	0.02	310	152	50.6	1.07 1.45	0.62 0.90	0.84 1.22 1.08 1.27	4.31 4.79	1.48 2.00 1.69 2.00
1/8 – 5052 – .001p	guar typ	min av	64.0 71.1	3.2	0.03	483	214	71.3	1.97 2.34	1.16 1.52	1.58 2.06 1.88 2.07	6.16 6.85	2.79 3.75 3.17 3.75
3/16 – 5056 – .0007p	guar typ	min av	28.8 32.0	4.8	0.02	186	90.0	30.0	0.72 0.97	0.34 0.59	0.46 0.80 0.68 0.87	3.36 3.77	0.82 1.10 0.95 1.10
3/16 – 5056 – .001p	guar typ min	av	44.7 49.7	4.8	0.03	310	138	46.0	1.38 1.76	0.76 1.07	1.03 1.45 1.30 1.46	5.26 5.85	1.79 2.48 2.13 2.48
1/8 – 5056 – .0007p	guar typ	min av	44.7 49.7	3.2	0.02	310	138	46.0	1.38 1.76	0.76 1.07	1.03 1.45 1.30 1.46	5.26 5.85	1.79 2.48 2.13 2.48
1/8 – 5056 – .001p	guar typ	min av	64.0 71.1	3.2	0.03	483	193	64.3	2.41 2.93	1.41 1.76	1.92 2.39 2.22 2.39	7.60 8.45	3.44 4.62 4.03 4.62

* Designation key: see Fig. 1.2.9

** Basis of the insert capability plots, Sect. 2.1.2.2; the values are considered as P = 90%; not tested properties are taken from suppliers' data sheet.

Designation*	Properties taken from supplier's data sheet **	Properties determined by test ***	Density	Cell size	Foil*** thickness	Shear modulus			Shear strength			Perpend. strength Tensile	Perpend. strength Compr.
			γ_c kg/m^3	S_c mm	t_o mm	G_L N/mm^2	G_W N/mm^2	G_C N/mm^2	τ_{Lcrit} N/mm^2	τ_{Wcrit} N/mm^2	τ_{Ccrit} N/mm^2	$\sigma_{Ccrit\ t}$ N/mm^2	$\sigma_{Ccrit\ c}$ N/mm^2
HRH 10—1/8—1.8	guar typ	min av	25.9 28.8	3.2		25.5	13.8	4.6	0.45 0.62	0.25 0.34	0.34 0.48	2.71 3.00	0.59 0.90
HRH 10—1/8—3.0	guar typ	min av	43.2 48.0	3.2		48.3	24.1	8.0	1.12 1.24	0.59 0.66	0.63 0.90	4.59 5.10	1.86 2.28
HRH 10—1/8—4.0	guar typ	min av	57.6 64.0	3.2		63.5	32.4	10.8	1.55 1.69	0.77 0.97	1.05 1.32	6.63 7.36	3.24 3.86
HRH 10—3/16—2.0	guar typ	min av	28.8 32.0	4.8		29.0	15.2	5.1	0.50 0.76	0.28 0.38	0.38 0.52	3.08 3.42	0.72 1.03
HRH 10—3/16—3.0	guar typ	min av	43.2 48.0	4.8		48.3	24.1	8.0	0.93 1.24	0.46 0.66	0.63 0.90	4.59 5.10	1.86 2.28
HRH 10—3/16—4.0	guar typ	min av	57.6 64.0	4.8		63.5	32.4	10.8	1.55 1.69	0.77 0.97	1.05 1.32	6.63 7.36	3.24 3.86
HRP —3/16—4.0	guar typ	min av	28.8 32.0	4.8		79	34	11.3	1.45 1.79	0.76 0.96	1.03 1.31	7.11 7.90	3.31 4.14
HRP —3/16—5.5	guar typ	min av	75.6 64.0	4.8		134	59	19.7	2.55 2.93	1.31 1.52	1.78 2.08	10.44 11.60	5.17 6.48

*Designation key, see Fig. 1.2.9 **Basis of the insert capability plots, Sect. 2.1.2.2 ***Not available

Since the number of single foils in L-direction is 72 % greater than in W-direction, the effective core shear strength which is relevant for the insert load capability is

$$\tau_{c\ crit} = 1.36\ \tau_{w\ crit} \qquad (1.2.3)$$

This applies for guaranteed as well as for typical shear-strength values.

Usually the guaranteed minimum shear strength values $\tau_{w\ crit\ min}$ have to be used. The values listed in Tab. 1.2.7.1/2 are taken from MIL-C-7438 F and data sheets of the suppliers.

The typical values also presented in Tab. 1.2.7.1/2 are drawn from data sheets previously published by the core suppliers. A typical value is the expected average value stated by the supplier.

1.2.2.2.4 Tensile Strength of Core

The core underneath partially potted inserts (see section 1.3) loaded in tension may fail by tensile rupture.

The tensile strength of core perpendicular to the sandwich plane is not specified, either in the standards or in the suppliers' data sheets.

The tensile strength of the aluminium core is therefore defined by

$$\sigma_{c\ crit\ t} = \sigma_{o\ crit\ t}\ \gamma_c/\gamma_o \qquad (1.2.4)$$

where

$\sigma_{o\ crit\ t}$ = tensile strength of core material
= 270 N/mm² for AA 5052 H 38 (MIL-HDBK-5C) or
330 N/mm² for AA 5056 H 38

γ_c = core density (e. g. 32 kg/m³ for 3/16-5052-.0007 core)

γ_o = density of core material (e. g. 2800 kg/m³ for aluminium)

The typical values $\sigma_{c\ crit\ t\ typ}$ listed in Tab. 1.2.7.1 are based on the typical core density $\gamma_{c\ typ}$. The minimum values $\sigma_{c\ crit\ t\ min}$ take into account the maximum allowable scatter of core density values of ±10 %.

$$\sigma_{c\ crit\ t\ min} = 0.9\ \sigma_{o\ crit\ t}\ \gamma_c/\gamma_o \qquad (1.2.5)$$

As in case of the non-metallic cores, where the typical tensile strength of the core materials was not available, $\sigma_{c\ crit\ c\ typ}$ was equate to the compressive strength $\sigma_{c\ crit\ t\ typ}$. The minimum values $\sigma_{c\ crit\ t\ min}$ were calculated as

$$\sigma_{c\ crit\ t\ min} = 0.9\ \sigma_{c\ crit\ c\ typ} \qquad (1.2.6)$$

The tensile strength of non-metallic cores determined by this way and listed in Tab. 1.2.7.2 is considered very conservative.

1.2.2.2.5 Compressive Strength of Core

The core underneath partially potted inserts (see section 1.2.3.2.3) loaded in compression may fail by compressive rupture. The compressive strength $\sigma_{c\ crit\ c}$ of core perpendicular to sandwich plane is given as

$\sigma_{c\ crit\ c\ min}$ = minimum compression strength of core originating from MIL-C-7438F, respectively in case of non-metallic core from suppliers' data

$\sigma_{c\ crit\ c\ typ}$ = typical compression strength of core originating from core suppliers' data

1.2.2.3 Bonding Between Core and Facing Sheet

Failure of the core/facing bonding are not experienced in insert tests. The load transferred from the insert to the facings usually thin in spacecraft application is such low that it is easily transmitted by the bonding.

Note: The foot of the bracket connection needs a minimum diameter of at least equivalent to the potting diameter 2 bp, see section 1.3.4.

1.2.3 Definition of the Potting Compound

1.2.3.1 Potting Material

The standard potting material, applied in the manufacturing procedure (section 3.2), is a liquid two-component epoxy resin of reduced weight and simultaneously improved viscosity. This is achieved by the addition of glass micro balloons. Characteristic properties of this resin are that it can only be applied by injection with an air-pressurised gun and that it will not flow after injection, provided the correct viscosity is maintained.

The basic properties of a typical resin compound (Lekutherm X227) considered here are (at room temperature):

Density	γ_R	0.6 - 0.7 kg/dm³
Tensile strength	$\sigma_{R\ crit}$	14 N/mm²
Compressive strenth	σ_R	36 N/mm²
Shear strength	$\tau_{R\ crit}$	10 N/mm²
Tensile modulus	E_R	2300 N/mm²
Temperature resistance		up to 100 °C

Table 1.2.8: Potting Material Properties

The materials and the mixing and curing conditions are defined in the manufacturing procedure: section 3.2.3.2.3.2.

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1.2.3.2 Potting Dimensions

Unlike the insert's dimensions, the potting dimensions have a decisive influence on the insert load capability. The following dimensions are relevant (Fig. 1.2.10)

Effective potting radius	b_p
Real potting radius	b_R
Potting height	h_p

These dimensions are valid for Insert Type B of Tab. 1.2.3. The potting dimensions of the seldom used insert implemented during sandwich manufacturing (Type A) needs to be established individually.

1.2.3.2.1 Effective Potting Radius

The effective potting radius b_p is an analytical dimension describing the radial influence zone of the potting. b_p takes into account that the double cell walls adjacent to the potting, which are much stiffer and stronger than the single cell walls and which generally do not fail, can be considered as an integral part of the potting.

b_p is defined as the average distance of the nearest single cell walls surrounding the potting from the centre of the insert. $b = \frac{1}{n} \Sigma b_n$ see Fig. 1.2.10.

It depends on:

- o Insert radius b_i
- o Size of core cell S_c
- o Location of insert centre within the hexagonal cell.

For each combination of insert radius and cell size, the effective potting radius b_p attains a minimum value for a certain position of the insert centre within the hexagonal cell. This minimum is given by the formulas, Ref. [2]:

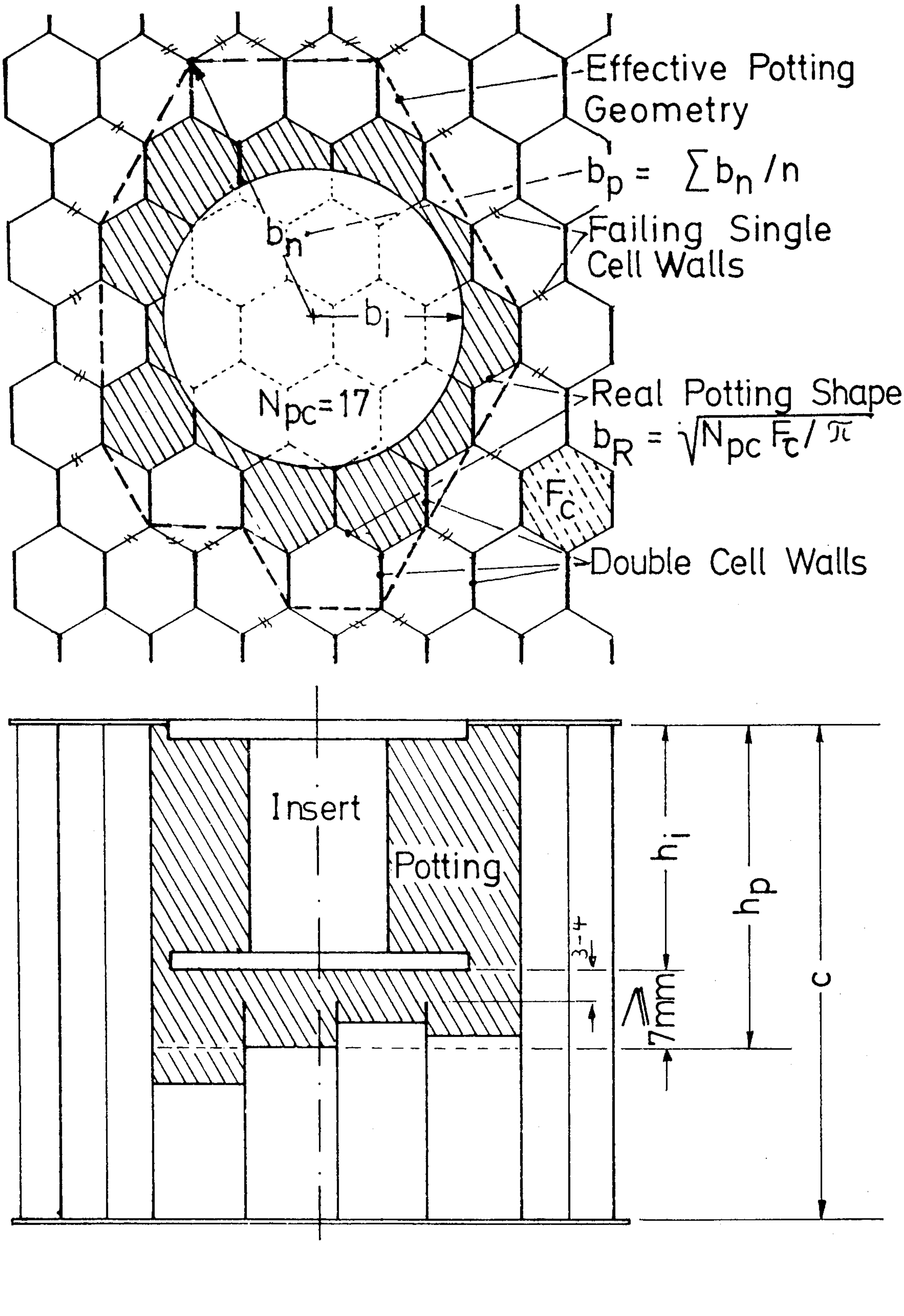

Fig. 1.2.10: Potting Geometry

a) Perforated core

$$b_{p\ min} = 0.93192\ b_i + 0.874\ S_c - 0.66151 \qquad (1.2.7.a)$$

b) Non-perforated core

$$b_{p\ min} = 0.9\ b_i + 0.7\ S_c \qquad (1.2.7.b)$$

The average or typical value of b_p is given by

a) Perforated core

$$b_{p\ typ} = 1.002064\ b_i + 0.940375\ S_c - 0.7113 \qquad (1.2.8.a)$$

b) Non-perforated core

$$b_{p\ typ} = b_i + 0.8\ S_c \qquad (1.2.8.b)$$

In Fig. 1.2.11 the effective potting radius determined by using the equations for non-perforated core (Equ. 1.2.7.b and 1.2.8.b) is plotted as a function of the insert diameter (see also Tab. 2.1.2.1/2).

b_p is relevant for the load participation of the core around and underneath the potting, as discussed in section 2.1.1 and Appendix A.

1.2.3.2.2 Real Potting Radius

The real potting radius b_R is the radius of the circle the area of which is identical to the real cross-sectional area F_R of the potting:

$$b_R = \sqrt{\frac{F_R}{\pi}} = \sqrt{\frac{N_{PC} \cdot F_C}{\pi}}$$

N_{pc} = number of core cells filled in with potting resin

F_c = cross-sectional area of one core cell

$= 0.95 \cdot 0.75 \cdot S_c^2 \cos\alpha$

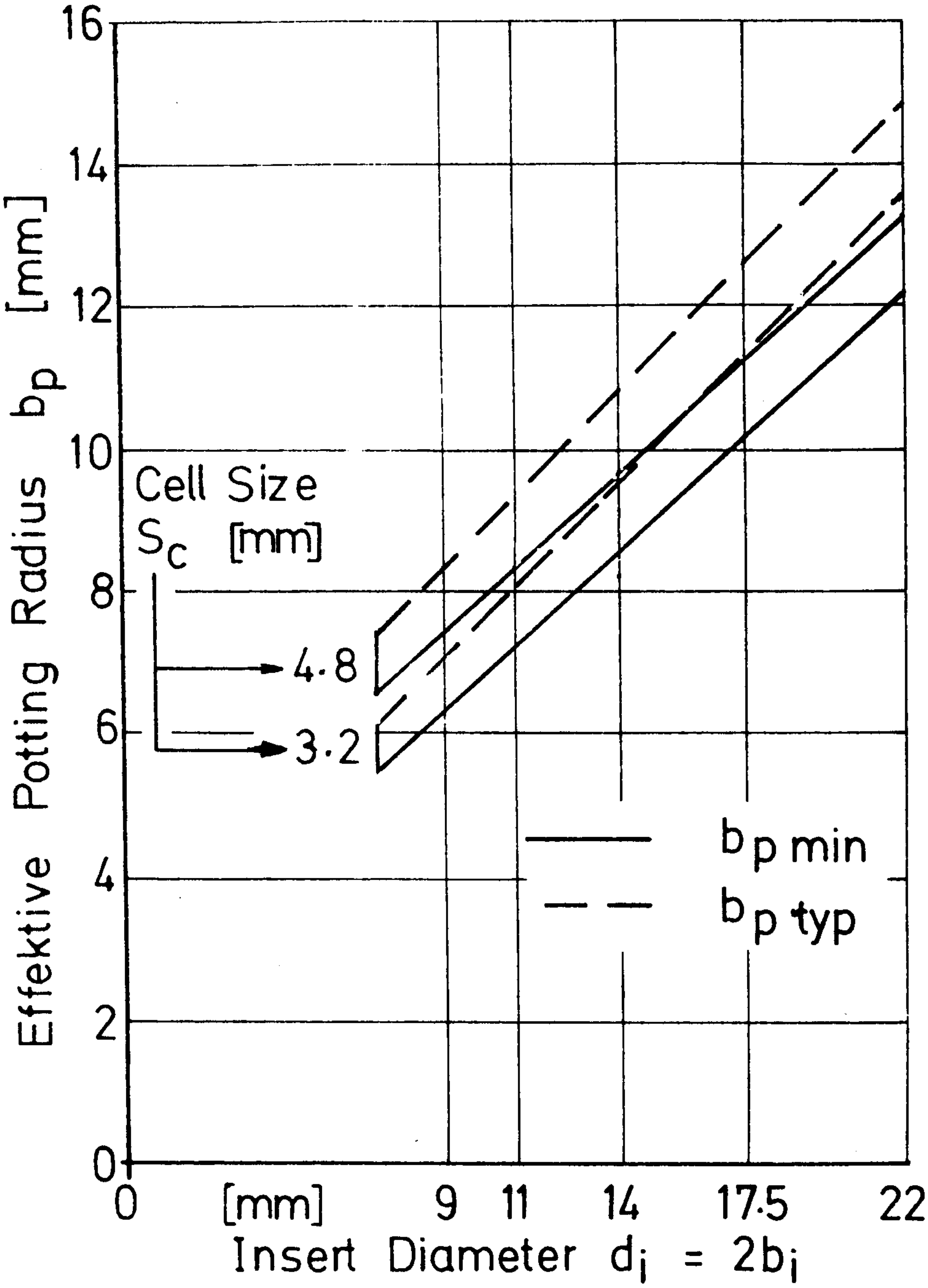

Fig. 1.2.11: Effective Potting Radius as a function of Insert Diameter (see also Tab. 2.1.2.1/2). Improved Data are achieved by using equations 1.2.7 and 1.2.8

where 0.95 = reduction for imperfect hexagonal shape of cell

S_c = nominal size of core cell

α = 30° for hexagonal honeycomb

F_c = 8.4 mm² if S_c = 3.2 mm

F_c = 19.0 mm² if S_c = 4.8 mm

Like b_p, the real potting radius b_R depends on b_i, S_c and the position of the insert centre with respect to the hexagonal cell.

The minimum real potting radius can be described by the formula, Ref. [2]:

$$b_R = b_i + 0.35\ S_c \tag{1.2.9}$$

The average or typical value of b_R is given by

$$b_{R\ typ} = b_i + 0.5\ S_c \tag{1.2.10}$$

Both functions are plotted in Fig. 1.2.12 for the two most frequently used cell sizes of 3.2 mm (1/8") and 4.8 mm (3/16").

b_R is relevant to the tensile failure of the potting.

1.2.3.2.3 Potting Height

The potting height h_p is the average depth down to which the core cells concerned are filled with potting resin.

The maximum possible potting height is identical to the core height c. This is fundamentally the case if the insert height is in the range between core height c and c-7 mm:

$$h_p = c \quad \text{for} \quad c \geq h_i \geq c-7\ \text{mm} \tag{1.2.11}$$

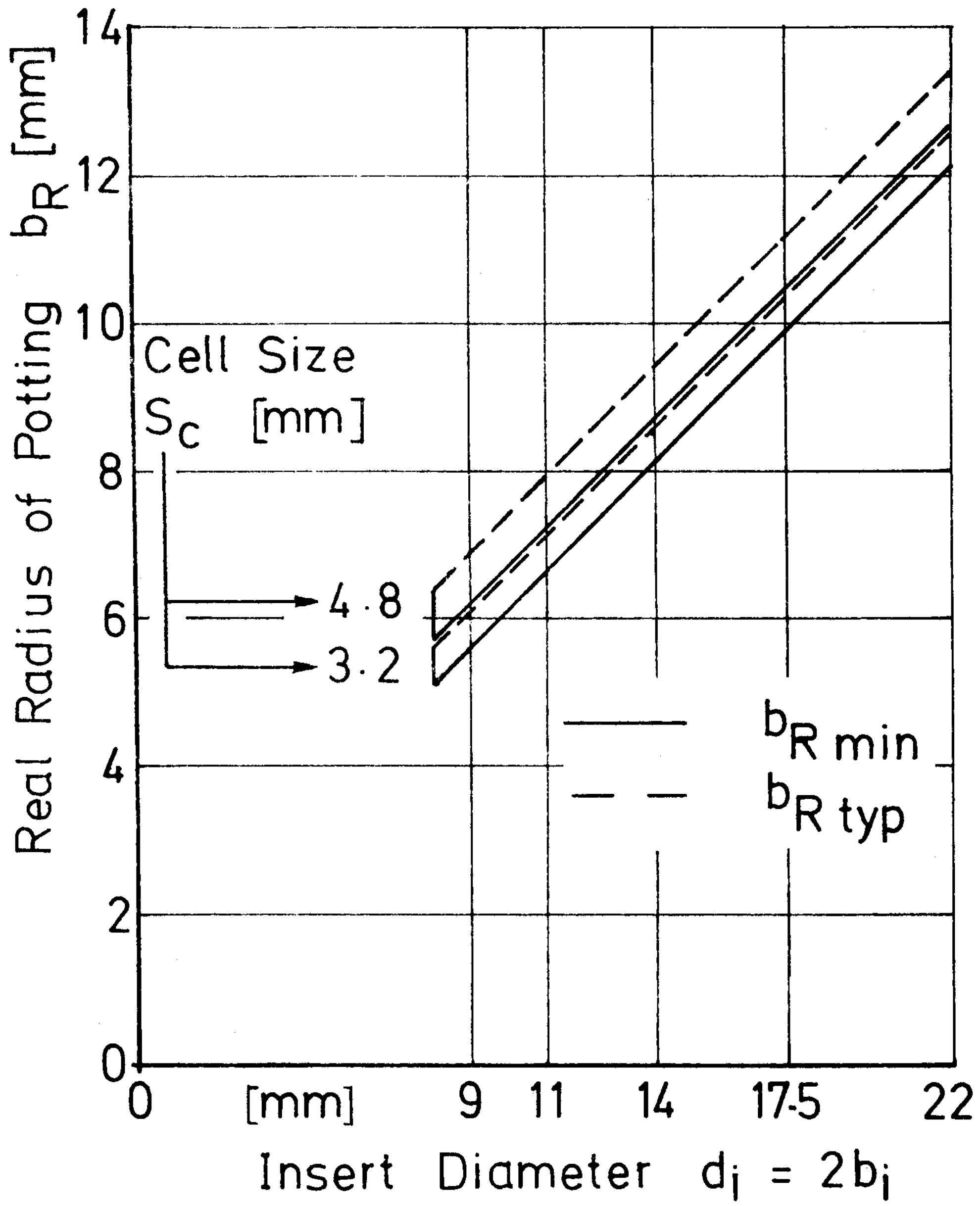

Fig. 1.2.12: Real Radius of Potting as a Function of Insert Diameter

This case is called "full potting" (Fig. 1.2.13). For greater core height ($c > h_i$ +7 mm) the potting height is generally smaller than the core height. This case is called "partial potting".

The minimum required potting height for partial potting depends on the insert height h_i:

$$h_{P\ min} = h_i + 7\ \mathrm{mm} \tag{1.2.12}$$

The 7 mm result from the following conditions:

- o The bore hole has to be 3 to 4 mm deeper than the insert height.
- o The core underneath the insert has at least to be connected by the potting resin over a depth of 3 mm.

$h_{P\ min}$, which is independent of core height, is to be used for the derivation of permitted design minima.

The average potting height - used for derivation of typical permissible design values - depends on the core height c and the size of the core cells S_c:

$$h_{P\ typ} = h_{p\ min} + A\ \mathrm{tgh}\ ((c - h_{p\ min})/h_{p\ min}) \tag{1.2.13}$$

with A = 2.5 mm for S_c 3.2 mm

and A = 5.0 mm for S_c = 4.8 mm.

For the frequently used insert height (h_i = 9 mm) the relation between potting height (h_P, $h_{P\ min}$, $h_{P\ typ}$) and core height c is shown in Fig. 1.2.13.

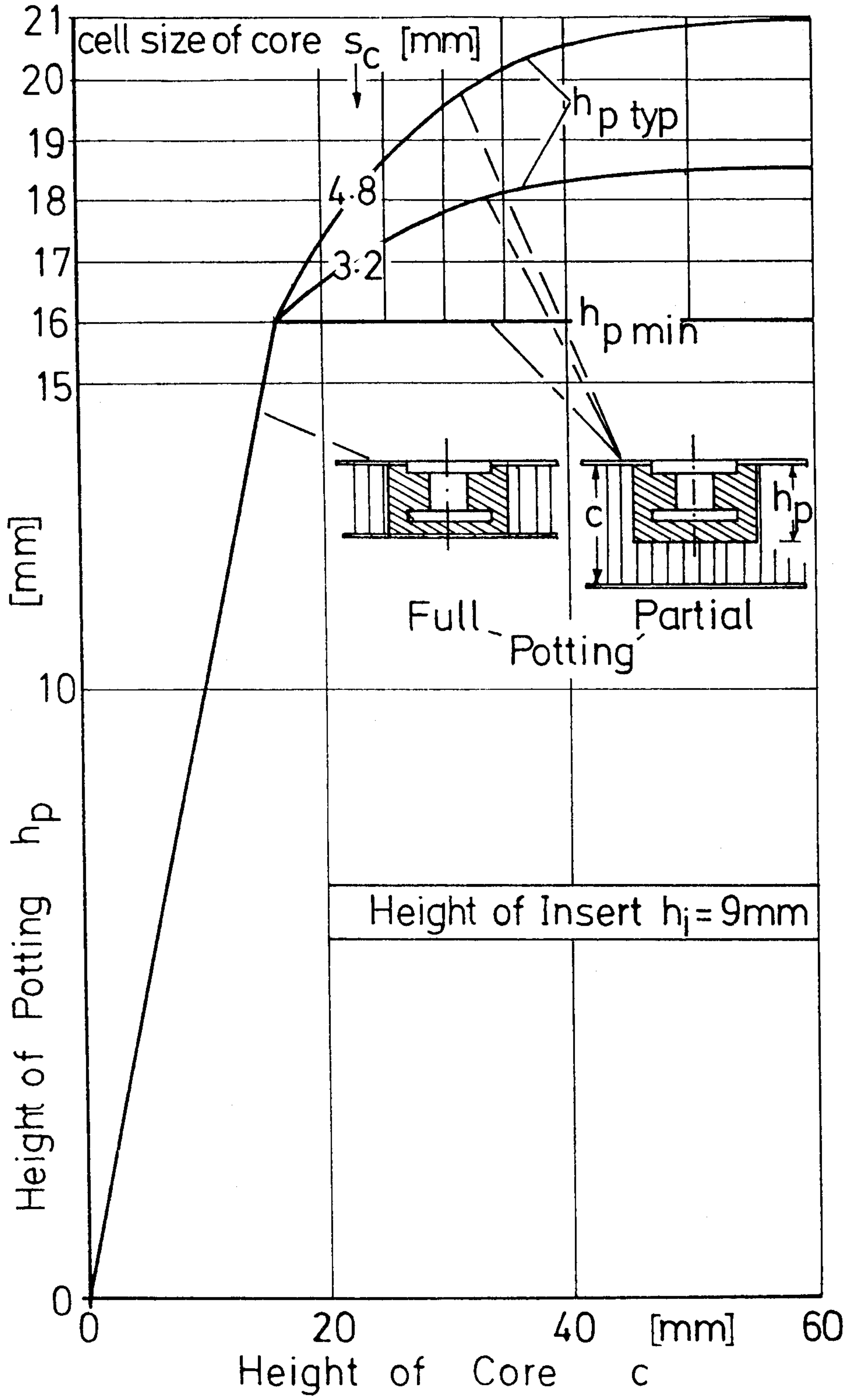

Fig. 1.2.13: Height of Potting as a Function of the Height of the Honeycomb Core

1.2.3.3 Potting Mass

The estimation of potting mass is necessary for the determination of the overall structural mass.

Fig. 1.2.14 shows the weight of potting depending on the height of core, cell size and various insert diameters.

The values are based on an insert height of 9 mm and a diameter of 14 mm, fully potted up to a core height of 16 mm, and partially potted at greater height of core.

For other heights of inserts, these values have to be corrected by coefficients, to be taken from Fig. 1.2.15.

Two cases, a partial potting and a full potting with insert height = core height have to be distinguished.

These weight data contain the mass of resin only. Masses for insert itself may be chosen as given in the standards (Appendix B).

The total mass of an insert system is identified by:

a) potting mass (see Fig. 1.2.14)

b) mass of insert elements (to be evaluated by using the values or dimensions of the standards)

c) reduced by mass of facing hole = $f \cdot b_i^2 \pi \cdot \rho$

d) reduced by mass of removed core (negligible).

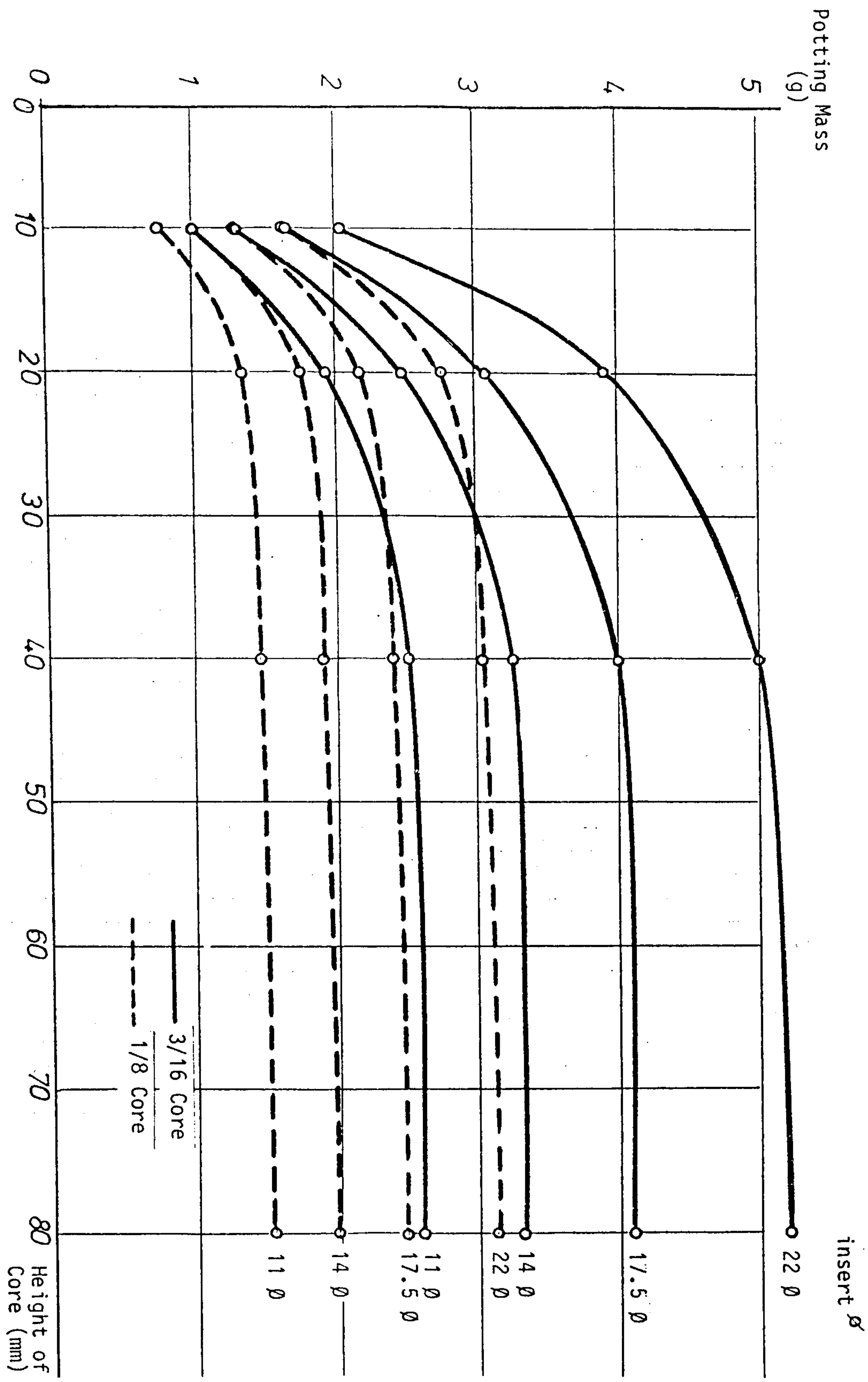

Fig. 1.2.14: Mean Weight of Potting Masses vs. Core Height and Insert Diameter

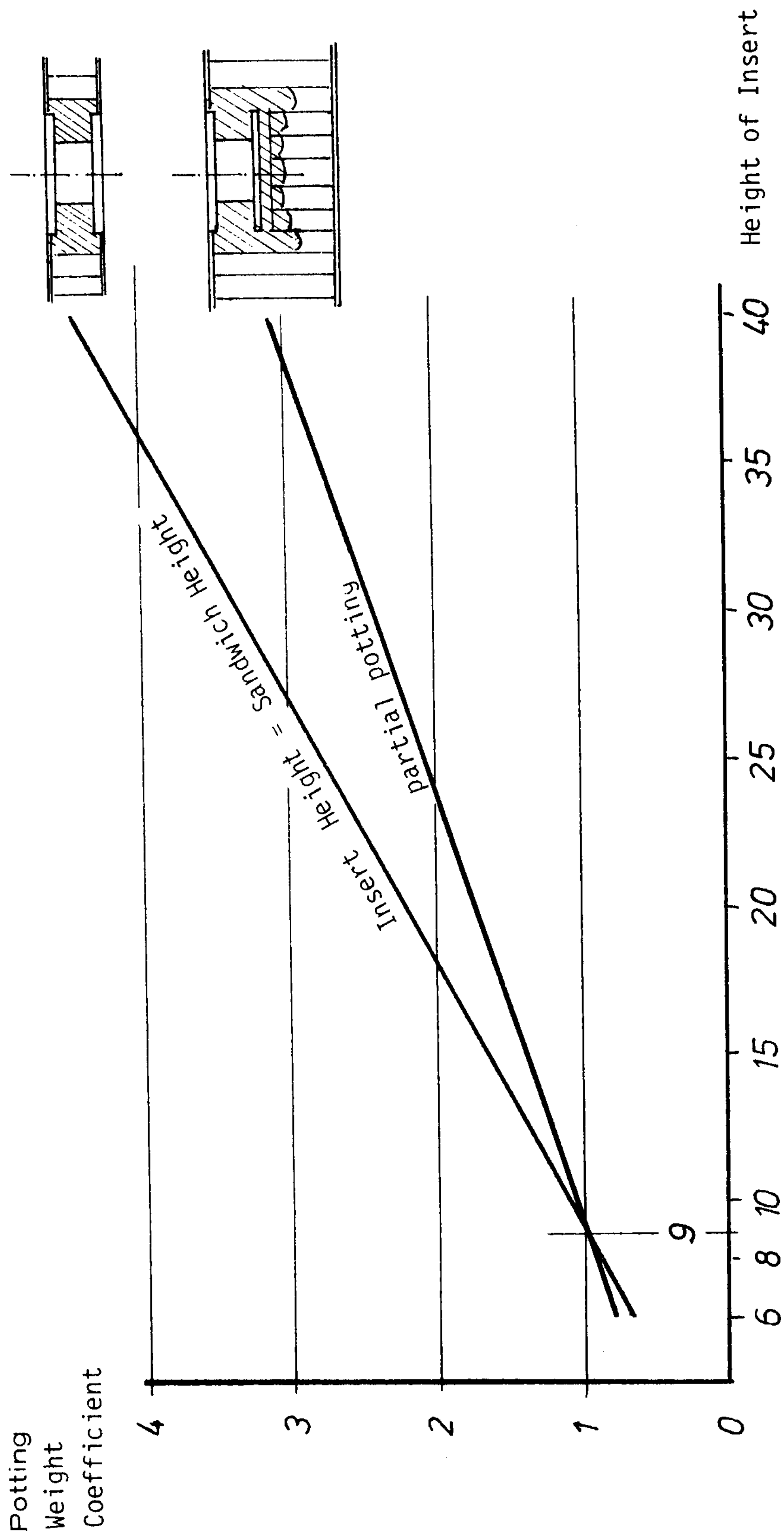

Fig. 1.2.15: Weight Coefficient for other Height of Insert than 9 mm

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As long as the core height is less than or equal to the minimum required potting height

$$h_c \leq h_1 + 7 \text{ mm}$$

the potting is considered as "full potting" where the potting height is equal to core height.

For partial potting (here for $h_c > h_1 + 7 = 16$ mm) the minimum and typical values deviate according to Fig. 1.2.13.

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1.3 Design Considerations and Applications

1.3.1 Insert Arrangement

Design requirements will govern the way in which inserts are incorporated in a sandwich structure. Fig. 1.2.16 shows several characteristic examples and lists the relevant sections of the handbook.

Among these examples, the insert with lateral axis (No. c) does not represent an advisable application case because the load carrying capability is very poor.

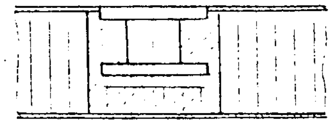
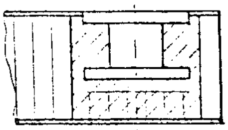
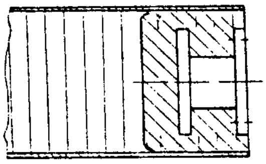
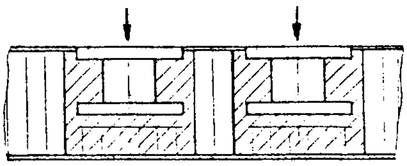
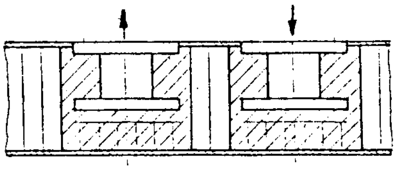
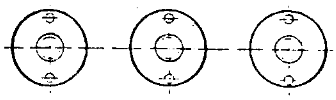
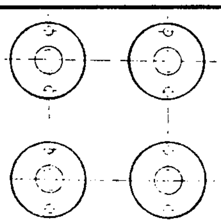
		Type of Arrangement	For Load Capability see Sect.
a		Single insert without edge influences	2.1.
b		Single insert near edges	2.3.1 2.3.2
c		Insert axis parallel to facings	
d		Adjacent inserts axially loaded in the same directions	2.2.1
e		Adjacent inserts axially loaded in opposite directions	2.2.2
f		Adjacent inserts in line (profile junction arrangement)	2.2
g		Adjacent inserts in group (bracket junction arrangement)	2.2

Fig. 1.2.16: Insert Arrangement

1.3.2 Mounting Modes

Positioning of inserts with respect to the surface of the sandwich panel depends upon mounting requirements.

Generally a flush-mounted insert is required, i.e. the upper surface of the insert is to be made flush with the face sheet surface (Fig. 1.2.17, mode a). Because it is practically impossible to set an insert accurately in position with x = o a small negative tolerance up to 0.03 mm is acceptable (Fig. 1.2.17, mode b). This is the normal mode of mounting. It also ensures good heat transfer from mounted electronic boxes or other heat developing equipment into the face sheet and minimises secondary bending effects.

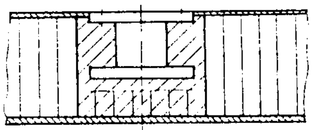
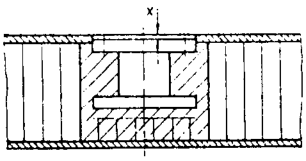
a		flush-mounted insert
b		recessed insert 0 mm < x < 0.03 mm

Fig. 1.2.17: Mounting Modes

1.3.3 Load Conditions

An insert transfers 5 basic types of load which may act singly or in combination (Fig. 1.2.18). If at all possible, design shall give preference to loadings in the insert axis or transverse to it, as shown by the first three types in the figure. When a load is acting in a direction forming an acute angle with the insert axis this load can be replaced by 2 rectangularly acting components thus producing tension and shear or compression and shear.

The introduction of a bending load is unfavourable, in view of the small bending strength and stiffness of the insert system.

Torsional loads on single inserts shall be restricted to screwing and locking torques only.

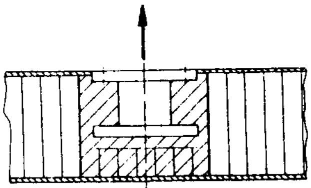
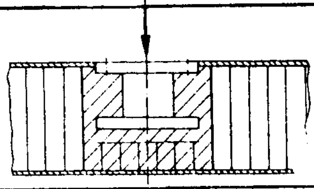
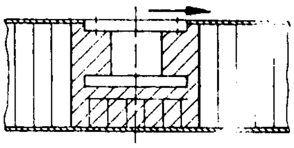
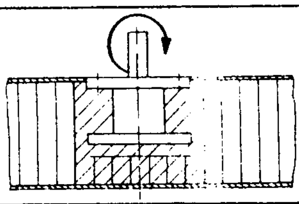
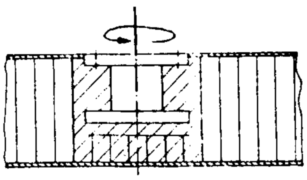
			For load capability see Section
a		Load normal to plane of the sandwich away from the surface "Tensile Load"	2.1.1
b		Load normal to the plane of the sandwich towards the surface "Compressive Load"	2.1.2
c		Load in plane of the facing "Shear Load"	2.1.3
d		**Bending load ±**	2.1.4
e		**Torsional load ±**	2.1.5

Fig. 1.2.18: Load Conditions

1.3.4 Junction of Components

In order to achieve a satisfactory junction of components the brackets shall exhibit a sufficiently large contact area at the connecting point.

The minimum dimension D shown in Fig. 1.2.19, mode a, shall be equal to the potting diameter, which is approximately the insert diameter shown in Fig. 1.2.11 plus 8 mm.

Versions b and c are to be avoided.

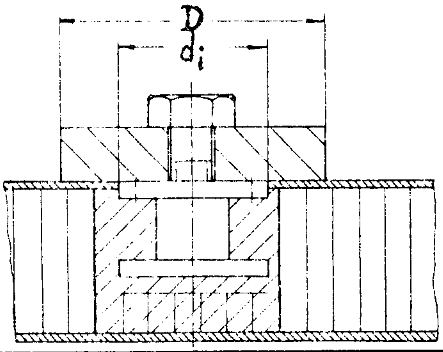
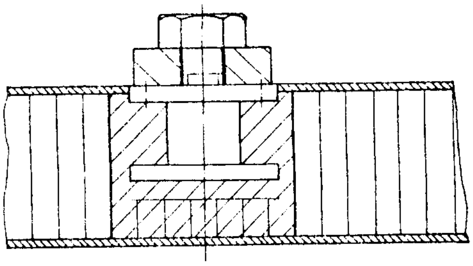
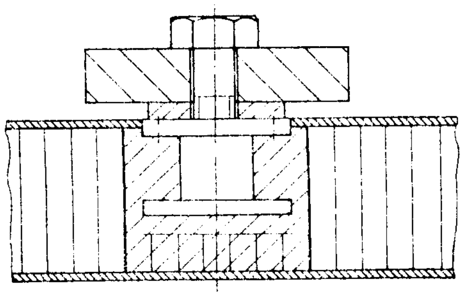
a		contact area greater than the potted area
b		contact area smaller than the insert flange area <u>incorrect</u> design
c		shimming plate smaller than the potted area <u>incorrect</u> design

Fig. 1.2.19: Connection Conditions

1.4 How to Provide an Adequate Insert Design

Though much information is provided in this handbook, a selection procedure for the most appropriate insert arrangement cannot be provided. The optimization with respect to sandwich configuration, the number of inserts, their pattern, the added mass, the related manufacturing problems and quality assurance provisions etc. are still to be maintained by the creative designer. This handbook provides detailed information - in a format easy accessible by the designer without extensive analytic work - related to all aspects of a typical spacecraft design, especially the

- o standardization of insert geometries and material
- o the sandwich panel characterization
- o the potting process and the related potting geometry
- o static strength and the fatigue life of inserts
- o manufacturing procedures, and
- o quality assurance provisions and test procedures.

Under respectation of the constraints provided here the designer should select the insert configuration in accordance to the well balanced priorities of requirements.

1.4.1 How to Select an Insert with Sufficient Strength

The static strength of an insert is considered successfully verified if its load-carrying cpability is in excess of the design loads (limit loads) multipled by a safety factor j.

$$P_{allowable} \geq P_{ult.} = P_{limit} \cdot j_n$$

If not defined differently in the program requirements, a safety factor of 1.5 is recommended against failure (see section 2.1.1.1.4).

1.4.2 Minimum and Average Insert Capability

a) Minimum insert load-carrying capability

The minimum insert capabilities $P_{ss\ min}$ plotted in section 2.1.1.2 (permissible tensile loads) are related to the minimum values of

- potting geometry ($b_{p\ min}$, $h_{p\ min}$)
- core strength of the metallic cores

  $\tau_{c\ crit\ min}$; $\sigma_{c\ crit\ t\ min}$; $\sigma_{c\ crit\ c\ min}$
- core strength of the non-metallic cores

  $\tau_{c\ crit\ guar}$; $\sigma_{c\ crit\ t\ guar}$; $\sigma_{c\ crit\ c\ guar}$

These permissible capability values are applicable without further investigations, provided that

- the core properties are in accordance with MIL-C-7438 F and with the national procurement specifications
- the manufacturing has been performed in accordance with the manufacturing and quality assurance specification as described in sections 3 and 5.

If the minimum material data and potting dimension apply, the probability of exceeding the given minimum load capability is 99 % with a confidence level of 95 %.

b) Average insert load carrying capability

The average insert capabilities $P_{SS\ av}$ plotted in sections 2.1.1.3 and 2.1.2.3 are related to the average or typical values of

- potting geometry ($b_{p\ typ}$, $h_{p\ typ}$)
- core strength of aluminium cores

  $t_{c\ crit\ av}$, $\sigma_{c\ crit\ t\ av}$, $\sigma_{c\ crit\ c\ av}$, respectively

- core strength of the non-metallic cores

  $t_{c\ crit\ typ}$, $\sigma_{c\ crit\ t\ typ}$, $\sigma_{c\ crit\ c\ typ}$

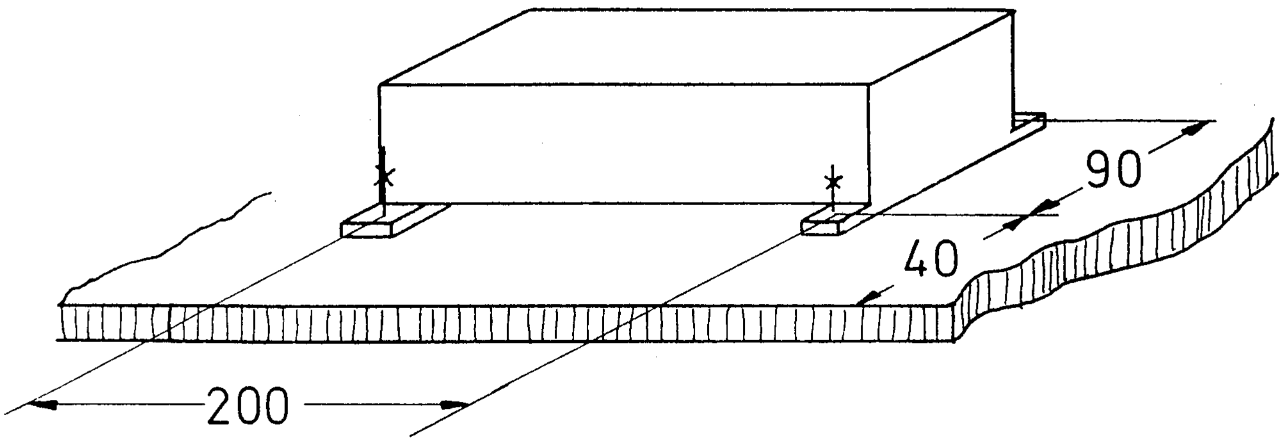
70 % of the average capability values are applicable without further investigations provided that:

- the core properties at least meet the typical/average values listed in Tab. 1.2.7.1
- the manufacturing has been performed in accordance with the manufacturing and quality assurance specification as described in sections 3 and 5.
- the load transfer is maintained by a set of inserts close together with different loads and by the potential of a re-destribution a reduced factor of safety (see section 2.1.1.1.4) may be justified.

1.4.3 Example of Insert Verification

Assuming a box is to be mounted on a sandwich panel at the four corners. The inserts are placed in a sandwich with

o	Core	:	3/16 - 5052 - .0007
o	Core height	:	30 mm
o	Facing	:	0.3 mm Al
o	Mass of the box	:	11 kg
o	Acceleration	:	20 g in all axes (For simplification the acceleration is assumed to act in the center of plane of the facing here.)
o	Temperatures	:	ambient



1) Loads

Total load : $F_r = m \cdot 20 \cdot 9.81 = 2200$ N

Ultimate load on each box corner : $P_{ult} = \dfrac{F_t \cdot 1.5}{4}$ (section 2.1.1.1.4) 4 bolts

$$P_{ult} = \frac{2200 \cdot 1.5}{4} = 825 \text{ N}$$

2) Selection of Insert

Tension : P_{SS} (b_i = 11) = 1090 N (section 2.1.2.2)

P_{SS} (b_i = 14) = 1220 N (section 2.1.2.2)

Compression: P_{SS} (d_i = 11) = 900 N (section 2.1.2.2)

P_{SS} (di = 14) = 1050 N (section 2.1.2.2)

(In case of insufficient compressive strength an increased foot diameter in excess to the potting elements 2 b_p may be chosen instead of an increased insert!)

Loads in Plane

$$Q_{SS} = 8\ b_p{}^2 \cdot \tau_{w_{crit}} + 2\ b_p \cdot f \cdot \sigma_{fy} \qquad \text{(Equ. 2.1.6)}$$

with $b_{p_{min}} = 0.93192 \cdot b_i + 0.874\ S_c - 0.66151$ (Equ. 1.2.6.a)

$b_{p_{min}}\ (d_i = 11) = 8.63$ mm (Tab. 2.1.2.1)

$b_{p_{min}}\ (d_i = 14) = 10.03$ mm

with $\tau_w = 0.32\ N/mm^2$ (Tab. 1.2.7.1)

$f = 0.3$ mm

$\sigma_{fy} = 270\ N/mm^2$ (Sect. 1.2.2.2.4)

$$(d_i = 11)\ Q_{SS} = 8 \cdot 8.63^2 \cdot 0.32 + 2 \cdot 0.3 \cdot 8.63 \cdot 270 = 1589\ N$$

$$(d_i = 14)\ Q_{SS} = 8 \cdot 10.03^2 \cdot 0.32 + 2 \cdot 0.3 \cdot 10.03 \cdot 270 = 1882\ N$$

The allowables are far beyond the requirements.

Grouping Effects (Sect. 2.2)

The potting radius $b_{p_{min}}$ was identified as

8.63 mm for $d_i = 11$ mm

10.03 mm for $d_i = 14$ mm

with $b_{p_1} = b_{p_2} \rightarrow b_{p_1}/b_{p_2} = 1$

The interference coefficient η_{is} becomes with a = 90 mm in accordance to Fig. 2.2.1:

$$(d_i = 11)\ \eta_{is} = \eta_{is}\ (a/b_{p_1}) = 1\ ;\ b_{p_1}/b_{p_2} = 1) = 10.4$$

$$(d_i = 14)\ \eta_{is} = \eta_{is}\ (a/b_{p_1}) = .9\ ;\ b_{p_1}/b_{p_2} = 1) = 0.95$$

(The distance in longitudinal direction is in excess of 10 b_{p_1}, no impact here.)

Edge Influence

The lowest distance of the outer insert to the free border is l = 40 mm. This results in a ratio

$$(d_i = 11)\ l/b_p = 40/\ 8.63 \cong 4.6 \qquad \text{(Sect. 2.3)}$$

$$(d_i = 14)\ l/b_p = 40/10.03 \cong 4.0$$

and

$$(d_i = 11)\ \eta_{EN} = 0.95$$

$$(d_i = 14)\ \eta_{EN} = 0.90$$

Total load capability under tension:

$$P_{max}\ (11\ \phi) = 1090 \cdot 1 \cdot 0.95 \cong 1035\ N$$

$$P_{max}\ (14\ \phi) = 1220 \cdot 0.85 \cdot 0.9 \cong 1043\ N$$

(both acceptable)

Life of Inserts (d_i = 11 mm) (Sect. 2.4)

The max. load during operation is

$$F_{worst} = 2200/4 = 550\ N\ \text{(amplitude)}$$

The mean ratio (with $F_A = |\hat{F}|$)

$$R = \frac{|\hat{F}| - 2F_A}{|\hat{F}|} = \frac{|\hat{F}| - 2\,|\hat{F}|}{|\hat{F}|} = -1$$

The corrections for the actual geometry are (h_c = 30 mm, f = 0.3)

$$\left.\begin{aligned} F_{EF} &= 1.2766 \\ F_{pp} &= 1.1052 \end{aligned}\right\} \quad F_{c-f} \cdot F_{pp} = 1.411$$

Assuming the sinusoidal vibration test at qualification as containing a safety factor of 1.33 this may result in the following peak load

$$\hat{F} = F_{cc} \cdot 1.33 = \frac{2200}{4} \cdot 1.33 = 722 \text{ N}$$

The tolerable loads are 1.411 times higher thatn shown in the plots, section 2.4.3.1 (here b_i = 11 mm).

F_{plot} [N]	$F_{tol} = F_{plot} \cdot 1.411$	N [Cycle]
600	846	1200
500	705	6500
400	565	50000

Under consideration of the sweep rate, the number of cycles occurring during sweep through the eigenfrequency are to determined.

$$N_o = f_e \cdot \Delta t$$

Δt = time to go through the bandwidth, BW.

With a scatter factor of 4 it has to be shown that

$$N \geq 4 \cdot N_o$$

Based upon test conditions, a decision is possible to accept an insert diameter of $2\ b_i = 11$ mm, or repeat the fatigue check with an insert diameter of 14 mm.

SECTION 2.0: INSERT CAPABILITIES

2.1 STATIC STRENGTH CAPABILITIES OF A SINGLE INSERT WITHOUT EDGE INFLUENCES

2.1.1 Normal Tensile Load

2.1.1.1 General

2.1.1.1.1 Failure modes

The decisive failure modes affecting the static strength capability P_{SS} of an insert under tensile load in a sandwich panel are mainly influenced by the height of core c in combination with the height of potting h_p (Fig. 2.1.1):

(a) **Shear rupture of the core surrounding the potting**

For **fully potted** inserts, i.e. for $h_p = c$, the insert fails by shear rupture of the core surrounding the potting, especially by shear rupture of the undoubled core foils. Therefore, the capability limiting property is the core shear strength $\tau_{c\,crit}$ according to section 1.2.2.2.3 and to Table 1.2.7.1/2. The insert capability P_{crit} increases quasi-linearly with the core height c.

(b) **Tensile rupture of the core underneath the potting**

For **partially potted** inserts ($c > h_p$), the core underneath the potting is subjected to a tensile stress.

In the case of aluminium core, this tensile stress increases for constant h_p with increasing core height. However, up to a certain height of core, the insert still fails by shear rupture of core around the potting, and the insert capability P_{crit} still increases quasi-linearly with core height c. this quasi-linear behaviour results from the early shear buckling of the single core foils, which maintains an approximately constant shear stress over the total core height. Although partially potted, the insert exhibits the same behaviour as that of a fully potted insert.

If $c - h_p$ attains a certain limit, the tensile stress underneath the potting reaches the tensile strength $\sigma_{c\,crit\,t}$ of the core, as defined in section 1.2.2.2.4 and Table 1.2.7.1. For greater core height, the shear rupture of core around the potting and the tensile rupture of core underneath the insert occur together: the insert capability is then simultaneously limited by $\tau_{c\,crit}$ and $\sigma_{c\,crit\,t}$ and is practically independent of further increase in core height.

In the case of nonmetallic cores (e.g. NOMEX, GFRP), the insert capability for constant h_p increases only slightly with increasing core height c. The reason why this behaviour differs from that of aluminium cores is that the rigid nonmetallic cores cannot adequately distribute stress concentrations by means of local deformations.

The stress concentration at the lower flange of the partially potted insert is considered to be conservatively accounted for by a stress-concentration factor for partial potting, K_{tpp}; see Appendix A 1.2.

NOTE – Nonmetallic core

The capabilities of inserts in nonmetallic core are determined by utilisation of measured core properties in combination with an analytical model verified primarily with metallic cores. They may be used for preliminary design and need to be substantiated by testing of the actual configuration.

In the case of a shallow, flexible, nonmetallic core and stiff, relatively thick, metallic facings, the load applied normal to the panel may be borne primarily by the facings. The strength of the facing needs to be checked, in order to ensure that the load distribution defined by the analytical model is still valid. The load in one facing may be approximated by $P_f = P_{ss}/2 - b_p\, c$. The criterion that this load can be transmitted by both facings has not been taken into account in the plotting of the graphs presented in the following pages. (A check of the kind just mentioned is not required for inserts in metallic core, since the model has been verified by many tests that implicitly covered this point.)

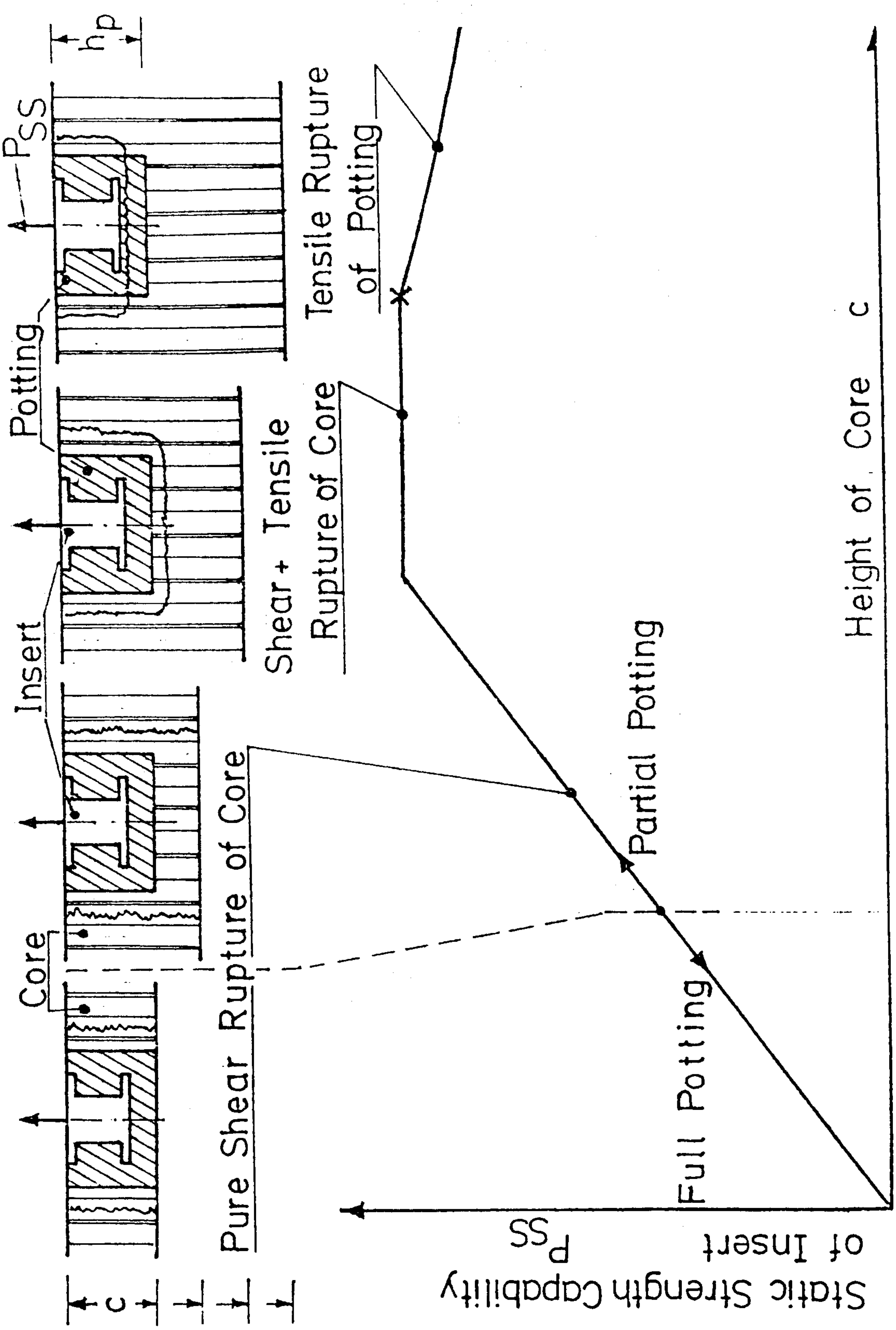


Fig. 2.1.1: Failure Modes in Relation to the Height of Core

c) Tensile rupture of the potting underneath the insert

Like the core underneath the potting, the potting underneath the insert is subjected to a tensile stress which increases with increasing core height. For a certain core height this stress may exceed the tensile strength $\sigma_{R\ crit}$ of the potting resin before the tensile strength $\sigma_{c\ crit\ t}$ of the core underneath the potting is reached. This is the case for heavy cores and may already occur for fully potted inserts. A further increase in the core height results in a slight decrease in the insert capability because P_{crit} is then only limited by $\sigma_{R\ crit}$. Owing to the rigidity of the potting, no advantage can be taken from the shear strength of the core: the shear stresses in the core around the potting decrease with a further increase of the core height c.

For the usual potting resin (syntactic foam) the tensile strength values are

$$\sigma_{R\ crit\ min} = 9\ \mathrm{N/mm^2}$$
$$\sigma_{R\ crit\ typ} = 12\ \mathrm{N/mm^2}$$

These values include the effective stress concentration K_t, as generated from insert tests, and are therefore lower than material strength as given in section 1.2.3.1. In view of this, one can conclude that the K_t value does not exceed 1.8.

2.1.1.1.2 Basic Parameters

The basic parameters for the determination of the capability of inserts under tensile load are related to (see also Tab. 2.1.1 and 2.1.2.1/2)

- o the facing sheets:
  - facing thickness f
  - facing material with E_f = Young's modulus and ν_f = Poisson's ratio

- o the insert:
  - diameter of insert d_i influencing the potting radius b_p
  - height of insert h_i influencing the potting height h_p

- o the core:
  - height of core c
  - cell size S_c — shear modulus G_c
  - foil thickness t_o influencing shear strength $\tau_{c\ crit}$
  - core material — tensile strength $\sigma_{c\ crit\ t}$

	Properties of Components	Minimum Values for $P_{SS\ t\ min}$ according to		Average/Typical Values for $P_{SS\ t\ av}$ according to	
Sheet	Thickness	f		f	
	Young's Modulus	E_F		E_F	
	Poisson's Ratio	ν_F		ν_F	
Potting	Effective Radius	$b_{p\ min}$	Equ. 1.2.6.a/b Fig. 1.2.8 Tab. 2.1.2.1/2	b_p typ	Equ. 1.2.7.a/b Fig. 1.2.8 Tab. 2.1.2.1/2
	Real Radius	$b_{R\ min}$	Equ. 1.2.8 Fig. 1.2.10 Tab. 2.1.2.1/2	$b_{R\ typ}$	Equ. 1.2.9 Fig. 1.2.10 Tab. 2.1.2.1/2
	Height	$h_{p\ min}$	Equ. 1.2.10/11 Fig. 1.2.11	$h_{p\ typ}$	Equ. 1.2.12 Fig. 1.2.11
	Tensile Strength	$\sigma_{R\ crit\ min} = 9\ N/mm^2$		$\sigma_{R\ crit\ typ} = 12\ N/mm^2$	
Core	Height	c		c	
	Shear Modulus	G_c	Equ. 1.2.2 Tab. 1.2.7.1/2	G_c	Equ. 1.2.2 Tab. 1.2.7.1/2
	Shear Strength	$\tau_{c\ crit\ min}$	Equ. 1.2.3 Tab. 1.2.7.1/2	$\tau_{c\ crit\ typ}$	Equ. 1.2.3 Tab. 1.2.7.1/2
	Tensile Strength	$\sigma_{c\ crit\ min}$	Equ. 1.2.5/6 Tab. 1.2.7.1/2	$\sigma_{c\ crit\ typ}$	Equ. 1.2.4 Tab. 1.2.7.1/2
RC	Perforated core	$RC = 1.172-0.0063h_c-0.2641\cdot f$		$RC = 1.207-0.00544h_c-0.2088\cdot f$	
	Unperforated core	RC = 0.91		RC = 1	

Table 2.1.1 Properties to be used for the determination of the insert capability P_{SS} (tensile load)

Core Cell Size S_c = 4.8 mm ≙ 3/16"							
Insert Diameter d_i		9	11	14	17.5	22	mm
Radius of Potting b_p	min	7.70	8.63	10.03	11.66	13.75	mm
	typ	8.28	9.28	10.78	12.54	14.79	mm
Real potting Radius b_R	min	6.18	7.18	8.64	10.43	12.68	mm
	typ	6.9	7.9	9.4	11.15	13.4	mm

Core Cell Size S_c = 3.2 mm ≙ 1/8"							
Insert Diameter d_i		9	11	14	17.5	22	mm
Radius of Potting b_p	min	6.33	7.26	8.66	10.29	12.39	mm
	typ	6.49	7.42	8.82	10.45	12.55	mm
Real potting Radius b_R	min	5.62	6.62	8.12	9.87	11.12	mm
	typ	6.1	7.1	8.6	10.35	12.6	mm

$$b_{p\ min} = 0.93192 \cdot b_i + 0.874\ S_c - 0.66151; \quad b_{R\ min} = b_i + 0.35\ S_c;$$

$$b_{p\ typ} = 1.002064 \cdot b_i + 0.94035\ S_c - 0.7113; \quad b_{R\ typ} = b_i + 0.5\ S_c;$$

$$b_i = 0.5\ di$$

Tab. 2.1.2.1: Effective and Real Potting Radius as Function of Insert Diameter d_i for <u>Perforated Cores</u> (e.g. Aluminium)

Core Cell Size S_c = 4.8 mm ≙ 3/16"							
Insert Diameter d_i		9	11	14	17.5	22	mm
Radius of	min	7.41	8.31	9.66	11.24	13.26	mm
Potting b_p	typ	8.34	9.34	10.84	12.59	14.84	mm
Real potting	min	6.18	7.18	8.64	10.43	12.68	mm
Radius b_R	typ	6.9	7.9	9.4	11.15	13.4	mm

Core Cell Size S_c = 3.2 mm ≙ 1/8"							
Insert Diameter d_i		9	11	14	17.5	22	mm
Radius of	min	6.29	7.19	8.54	10.12	12.14	mm
Potting b_p	typ	7.04	8.06	9.56	11.31	13.56	mm
Real potting	min	5.62	6.62	8.12	9.87	12.12	mm
Radius b_R	typ	6.1	7.1	8.6	10.35	12.6	mm

$$b_{p\,min} = 0.9\ b_i + 0.7\ S_c \quad ; \quad b_{R\,min} = b_i + 0.35\ S_c \quad ;$$

$$b_{p\,typ} = b_i + 0.8\ S_c \quad ; \quad b_{R\,typ} = b_i + 0.5\ S_c \quad ;$$

$$b_i = 0.5\ d_i$$

Tab. 2.1.2.2: Effective and Real Potting Radius as Function of Insert Diameter d_i for Non-Perforated Cores (e.g. NOMEX, GFRP)

2.1.1.1.3 Minimum and Average Design Values

Two levels of insert capabilities have been determined and plotted as a function of core height in section 2.1.2.2 (Permissible Tensile/Compressive Load):

- o minimum insert capabilities $P_{ss\ min}$
- o average insert capabilities $P_{ss\ av}$

Minimum insert design values are based upon

- o Minimum strength properties of core shear strength exceeded by a probability of 90 %. In cases where those data were not available, minimum guaranteed values as provided by the supplier will be used. In this latter case an indication of this fact is given in the strength design plots.

- o Minimum potting dimensions are experienced as exceeded by a probability of 90 %. For perforated (aluminium) core where statistical data are available the formulation 1.2.7.a is used. For unperforated (NOMEX, GFRP) cores the formulation 1.2.7.b is used to determine the minimum potting dimensions.

- o Model correlation coefficient RC exceeded by 90 % of the tested/ analyzed inserts.

  RC for the perforated aluminium core:

  $$RC = 1.172 - 0.0063 \cdot h_c - 0.2641 \cdot f$$

  RC for other types of core:

  $$RC = 0.91$$

The possibility that the three minima with an individual probability of 90 % apply together is such unlikely that the resulting values are regarded as design "A" values (P = 99 %; CL = 95 %). However, due to the fact that the analytically determined values of partially potted inserts in non-metallic core are checked by far less tests than those in metallic core, these values should be used for preliminary design only.

In case that minimum core strength in receiving inspection is just in accordance to the "guaranteed minimum value" this fact is considered as still covered by the other conservative value, the safety factor of 1.5, section 2.1.1.1.4.

Average insert values are based upon:

- Average strength properties of core shear strength exceeded by a probability of 50 %. In cases where those data were not available the typical values as provided by the supplier will be used. In this latter case an indication of this fact is given in the strength design plots.

- Average potting dimensions are experienced as exceeded by a probability of 50 %. For perforated (aluminium) core where statistical data are available the formulation 1.2.8.a is used. For unperforated (NOMEX, GFRP) cores the formulation 1.2.8.b is used to determine the average potting dimensions.

- Model correlation coefficient RC exceeded by 50 % of the tested/analyzed inserts.

  RC for the perforated aluminium core:

  $$RC = 1.207 - 0.00544 \cdot h_c - 0.2641 \cdot f$$

  RC for other types of core:

  $$RC = 1$$

2.1.1.1.4 Safety Factors

The load-carrying capabilities provided are determined in case of the perforated aluminium cores under usage of statistical means on groups of several hundred samples. Based upon the variability identified, these given capabilities are considered as actually in agreement with design "A" values (P = 99 %; Cl = 95 %). Therefore to account for the high variability generally experienced, there is no further need for an increased safety factor if the implementation of the insert is performed adequately, i.e. in accordance with the manufacturing procedure.

A safety factor of 1.5 against the minimum "A" ultimate capabilities provided is therefore recommended if no other requirements exist for the program.

The insert capability is limited to loads resulting in large permanent deformations. As the initiation of significant deformation starts close to ultimate load, there is - under usage of a safety factor of 1.5 against ultimate capabilities - no reason for a separate verification of a "no permanent deformation" requirement with respect to failure of the insert due to core failure.

Under other environment or with respect to other unusual failure modes, e.g. under elevated temperatures, this might, however, be necessary.

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2.1.1.2 Permissible Tensile Loads

In the diagrams in section 2.1.2.2 (Permissible Tensile/Compressive Load) the capability of inserts to withstand tensile loading is plotted as a function of the core height c with facing sheet thickness f as parameter. The different figures are related to different insert diameter d_i and to different core types.

The occasional crosses (x) in some load capability curves denote a tensile rupture of the potting which generally should be avoided, e.g. by increasing the insert height h_i (see Para. 2.1.1.3).

The $P_{SS\ t\ min}$ values are regarded as design "A" values (P = 99 %; Cl = 95 %) for all cases where the usual incoming inspections are performed and the implementation of the inserts is performed in accordance with the manufacturing and quality assurance procedure in sections 3 and 5.

The $P_{SS\ t\ av}$ values should be achieved in Quality Control Testing. In addition, 70% of the average capability values are applicable to design without further investigation provided that

- o the core properties at least meet the typical/average values listed in Tab. 1.2.7.1/2
- o the manufacturing has been performed in accordance with the manufacturing and quality assurance in sections 3 and 5
- o the load transfer is maintained by a set of inserts close together with different loads and by the potential of a re-distribution a reduced factor of safety may be justified.

2.1.1.3 Influence of Insert Height h_i

The capability diagrams are established for an insert height h_i = 9 mm. But the diagrams are also applicable for other h_i-values. A modification of h_i will shift only the break of the curves towards lower or higher c-values according to the relation

$$C'^* = C' + h_i^* - h_i \qquad (2.1.3)$$

with

h_i = basic insert height = 9 mm
h_i^* = new insert height
C' = c-value at curve break for basic insert height h_i
C'^* = new c-value at curve break for new insert height h_i^*

This shifting is schematically shown in Fig. 2.1.3.

The increase in h_i permits an increase in the insert capability only for those cases, where the failure occurs in the core underneath the potting or in the potting underneath the insert.

An increase in h_i is especially recommended if a rupture of the potting underneath the insert may be expected.

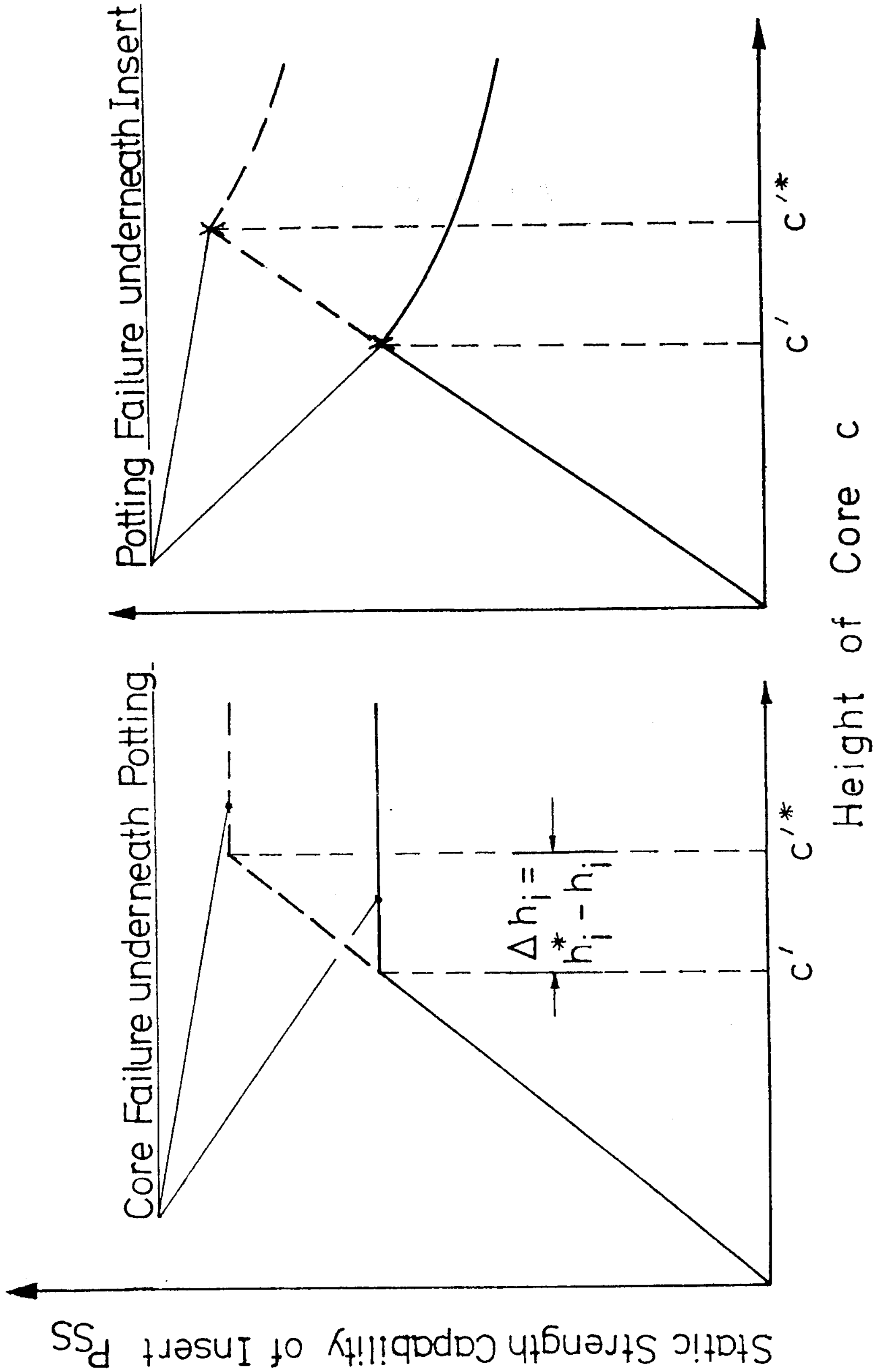

Fig. 2.1.3: Influence of Insert Height h_i on Insert Capability

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2.1.2 Normal Compressive Load

2.1.2.1 General

The statements made in section 2.1.1.1 (Normal Tensile Load, General) are also valid for the capability of inserts under compressive load taking into account the following exceptions:

a) For partially potted inserts the tensile strength $\sigma_{c\ crit\ t}$ of core underneath the potting must be replaced by the compressive strength $\sigma_{c\ crit\ c}$ as listed in Tab. 1.2.7.1/2.

b) The strength of the potting no longer has a limiting influence on the insert capability, because the compressive strength of the potting is far higher than the tensile strength of the potting and even higher than the compressive strength of the core.

c) For greater facing sheet thickness ($f \geq 0.6$ mm) the insert capability is reduced, because a rupture of bonding between upper facing sheet and core may occur in the vicinity of the insert. This has been considered by neglecting the load contribution of the upper facing sheet.

d) The minimum insert capability is given by

$$P_{SS\ c\ min} = RC \cdot P_{crit\ min} \qquad (2.1.1)$$

with: $RC = 0.89$

e) The average insert capability is given by

$$P_{SS\ c\ av} = RC \cdot P_{crit\ av} \qquad (2.1.2)$$

with: $RC = 1$

2.1.2.2 Permissible Compressive Loads

The statements made in section 2.1.1.2 (Permissible Tensile Loads) are also valid with regard to permissible compressive loads.

The two determined levels of insert capabilities are plotted below as function of the core height.

Permissible Static Tensile/Compressive Loading of inserts

- DIAGRAMS -

Core Types
(Designation Key: see Fig. 1.2.9)

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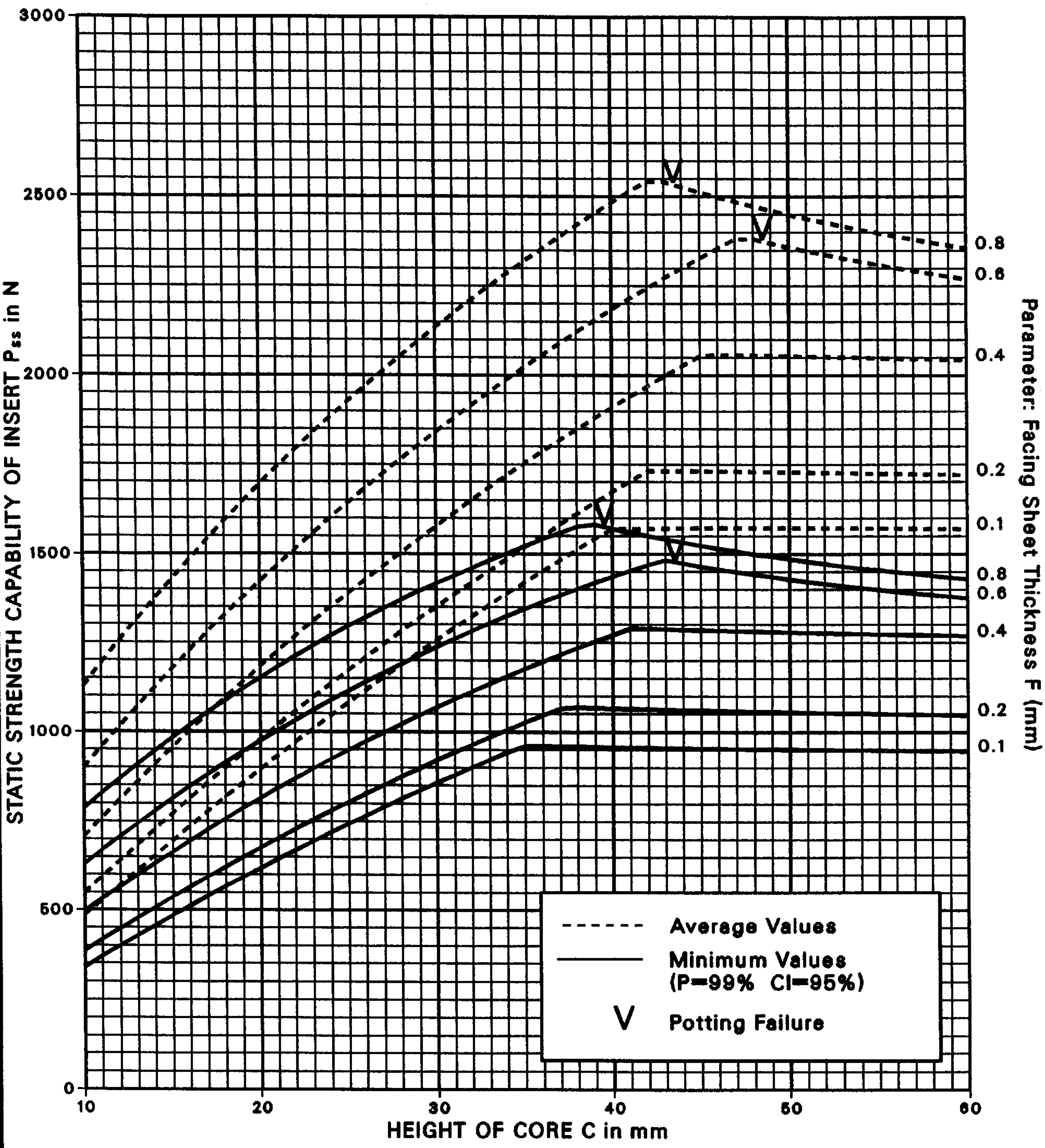
1. 3/16 – 5052 – 0.0007 Core

Insert Height h = 9 mm	Facing Material AL 2024

Load : **Tension**

Insert Diameter: **9.0 mm**

Core : **3/16-5052-.0007**

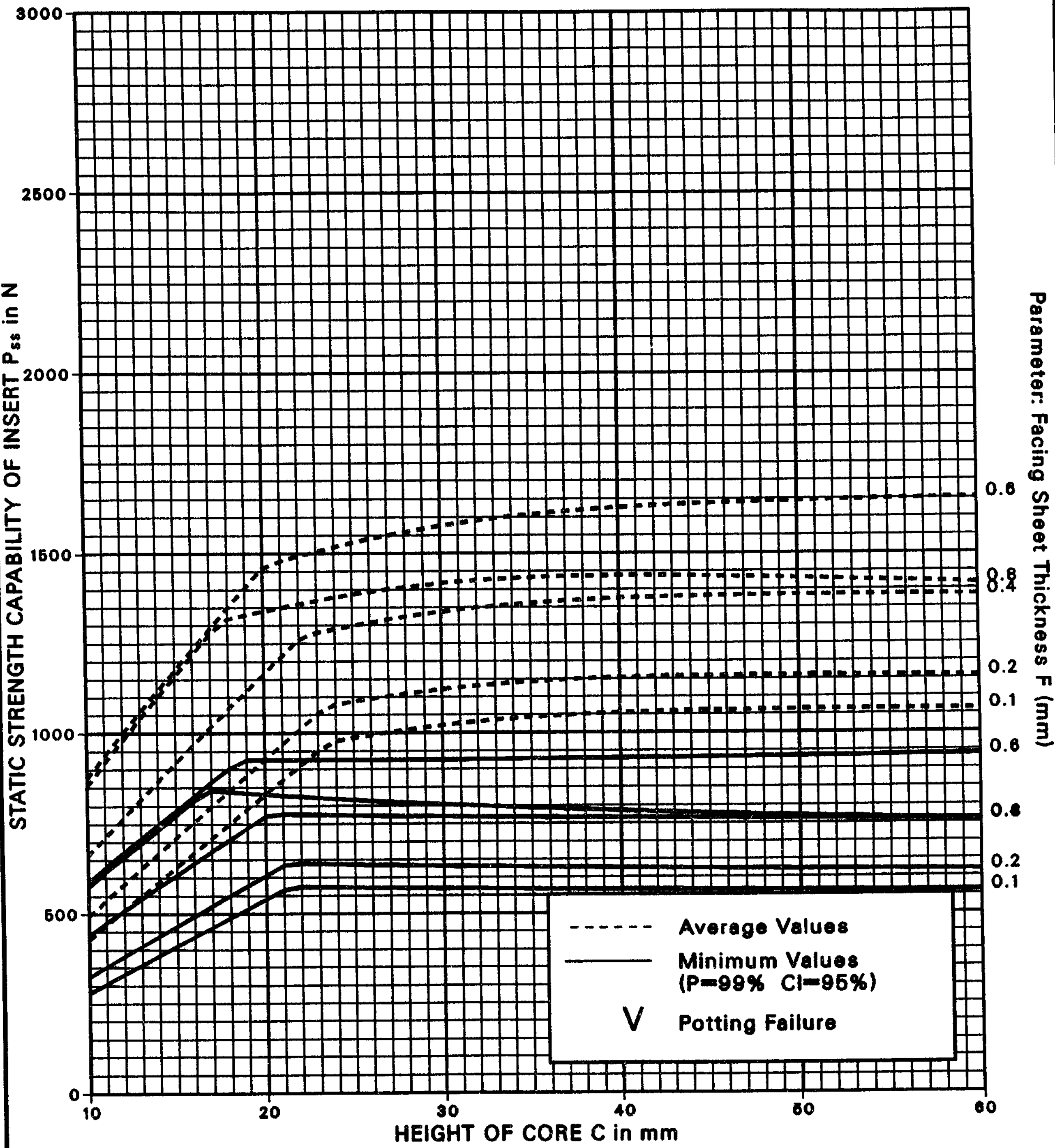


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Compression**

Insert Diameter: **9.0 mm**

Core : **3/16-5052-.0007**

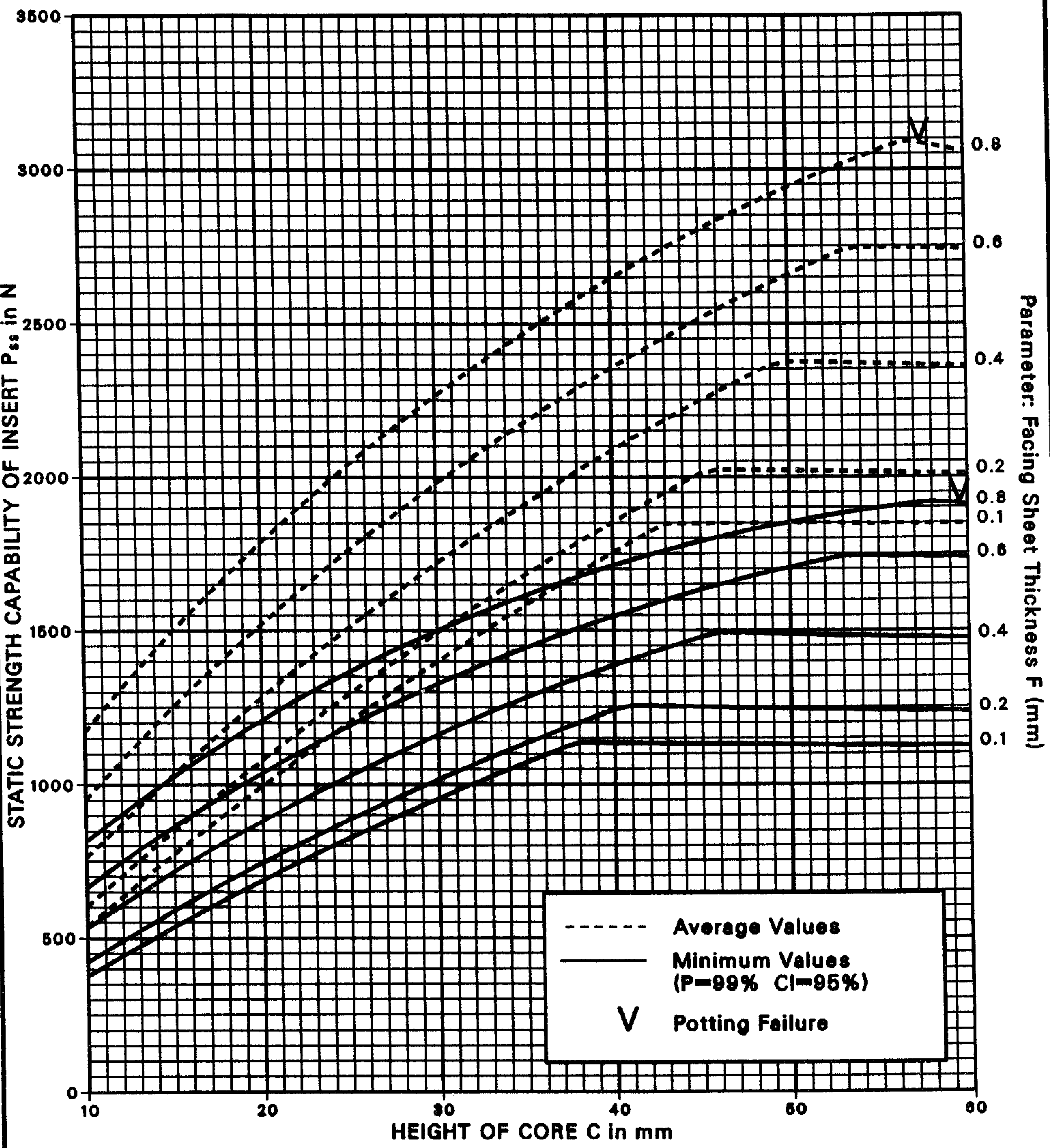


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **11.0 mm**

Core : **3/16-5052-.0007**

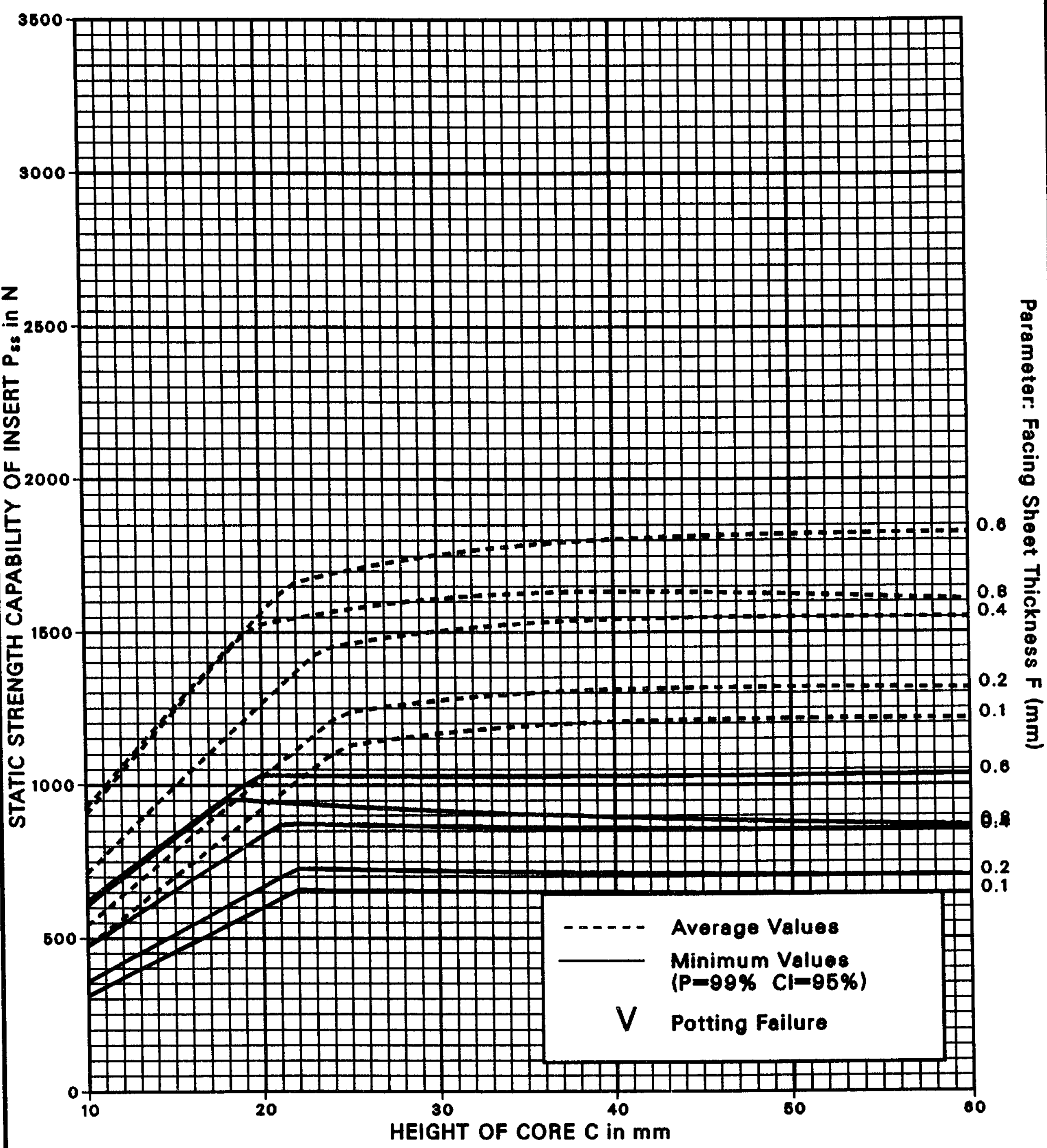


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Compression**

Insert Diameter: **11.0 mm**

Core : **3/16-5052-.0007**

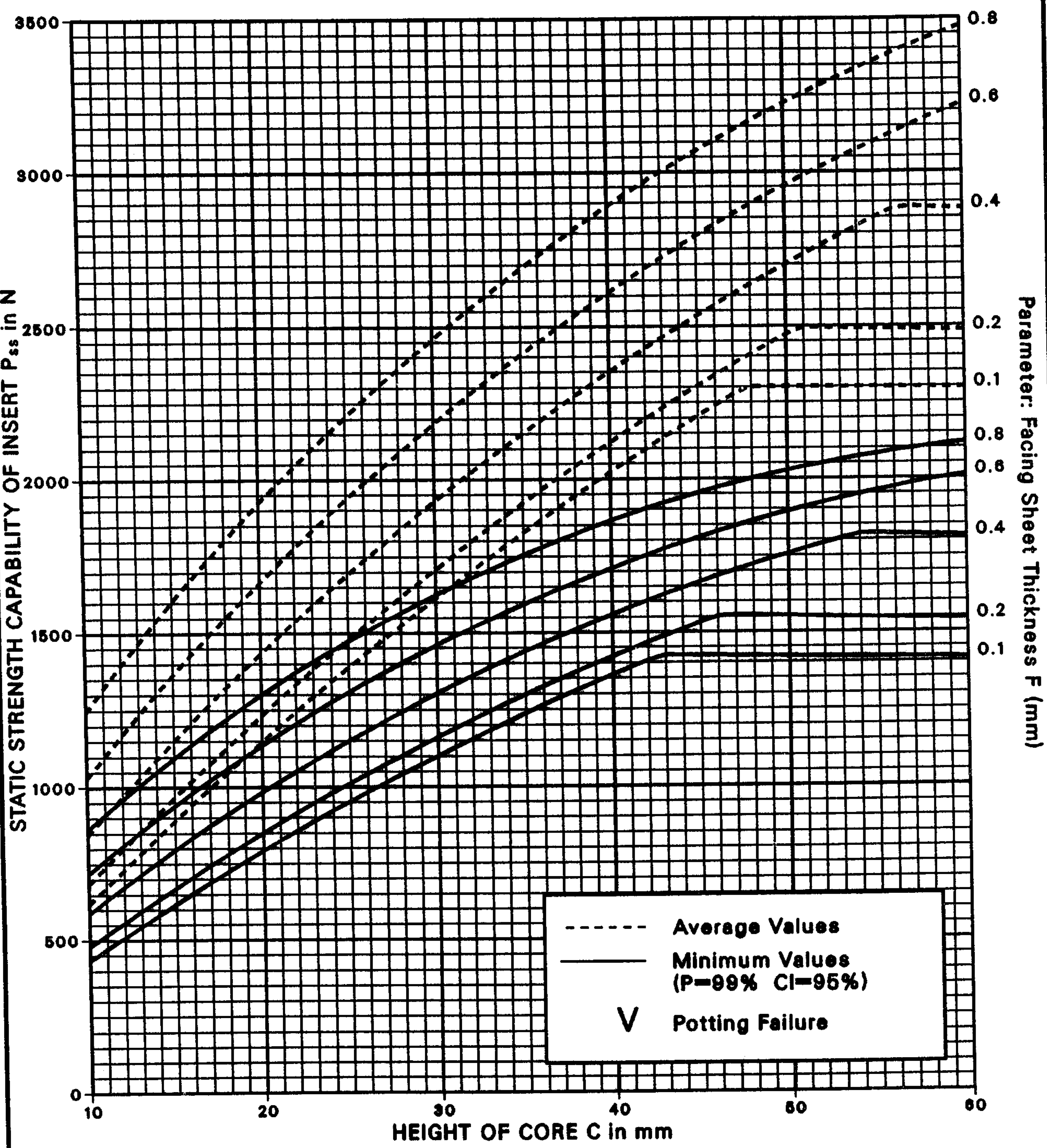


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Tension**

Insert Diameter: **14.0 mm**

Core : **3/16-5052-.0007**

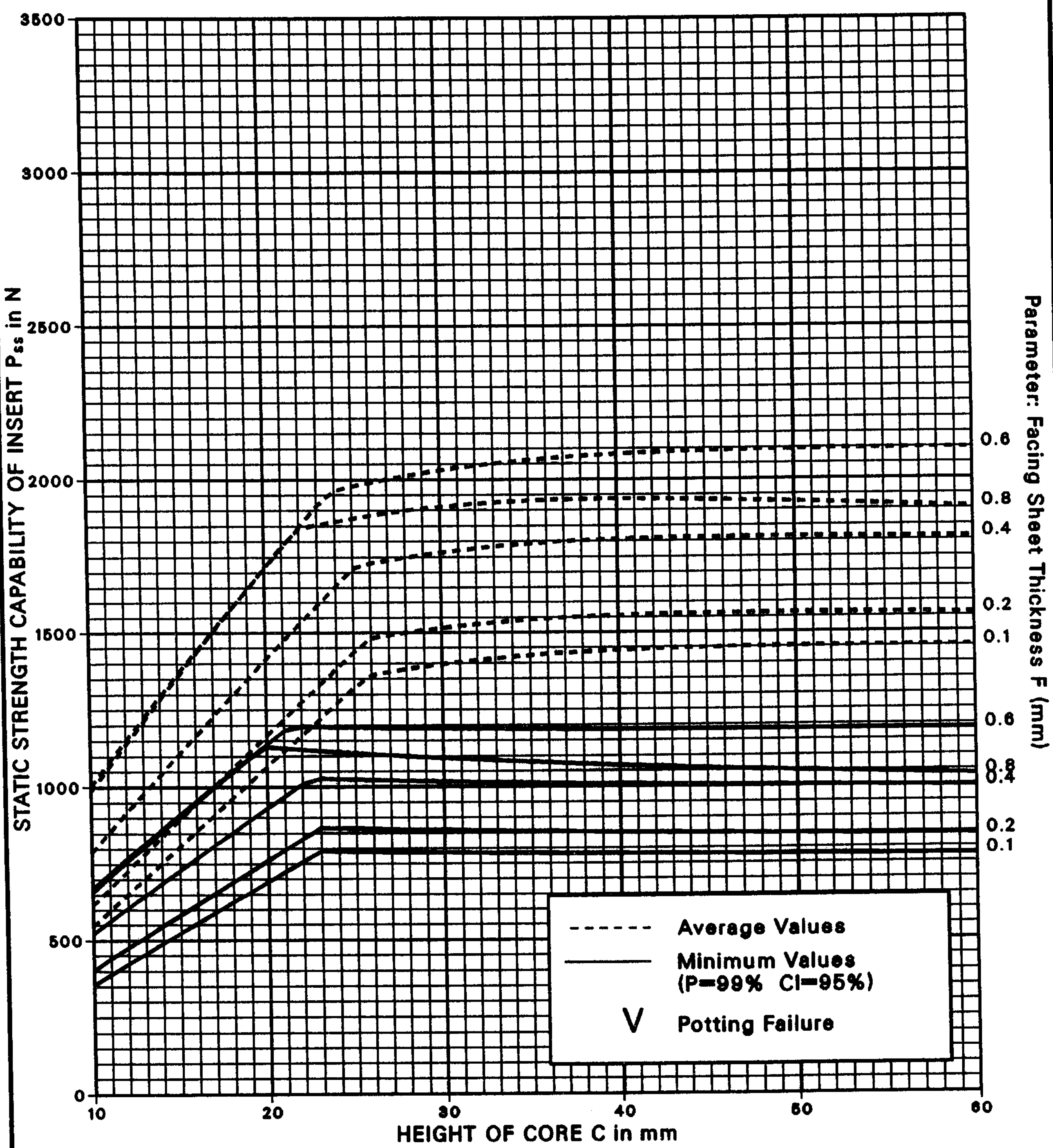


Insert Height h = 9 mm	Facing Material AL 2024

Load : Compression

Insert Diameter: 14.0 mm

Core : 3/16-5052-.0007



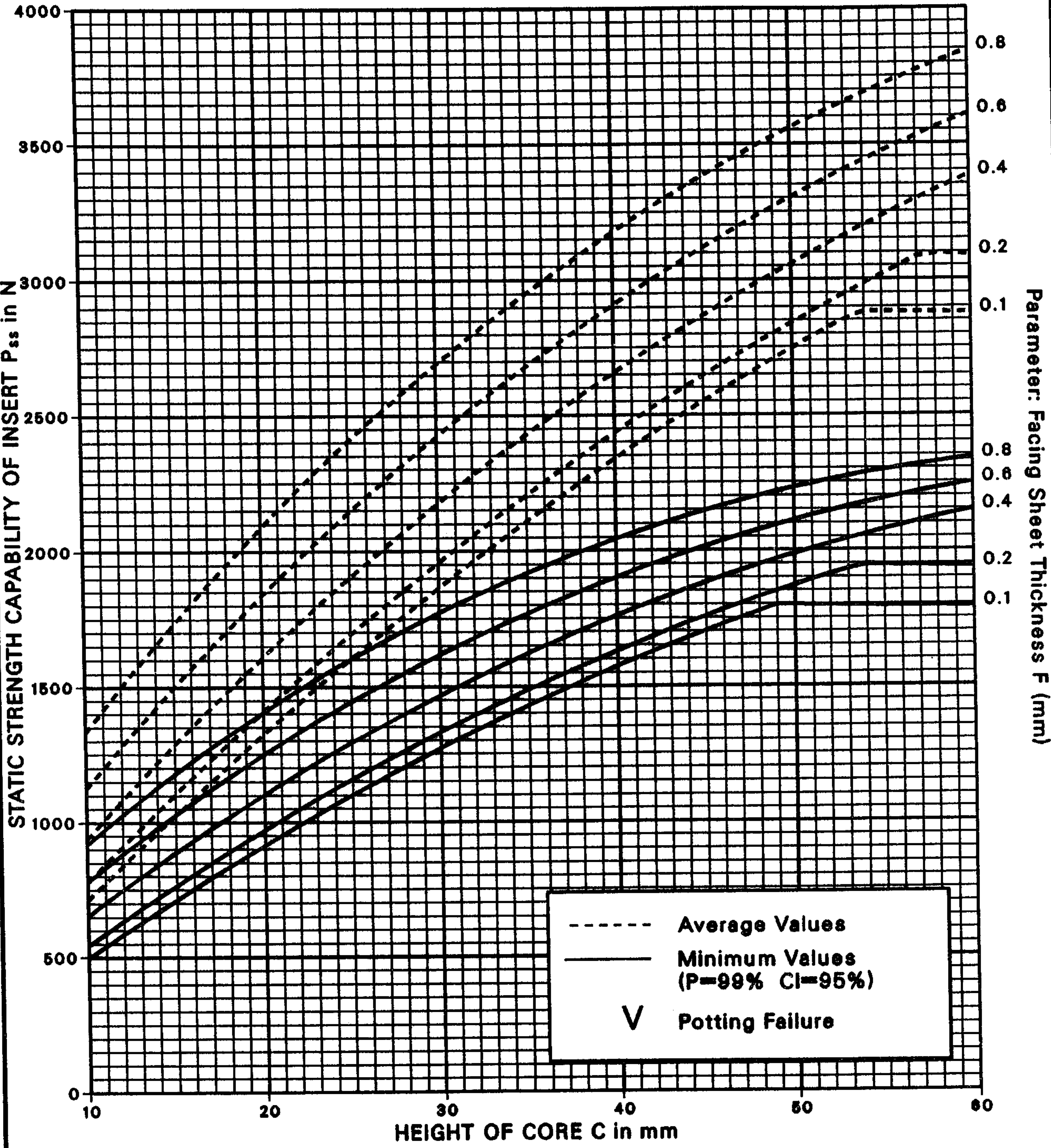
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **17.5 mm**

Core : **3/16-5052-.0007**

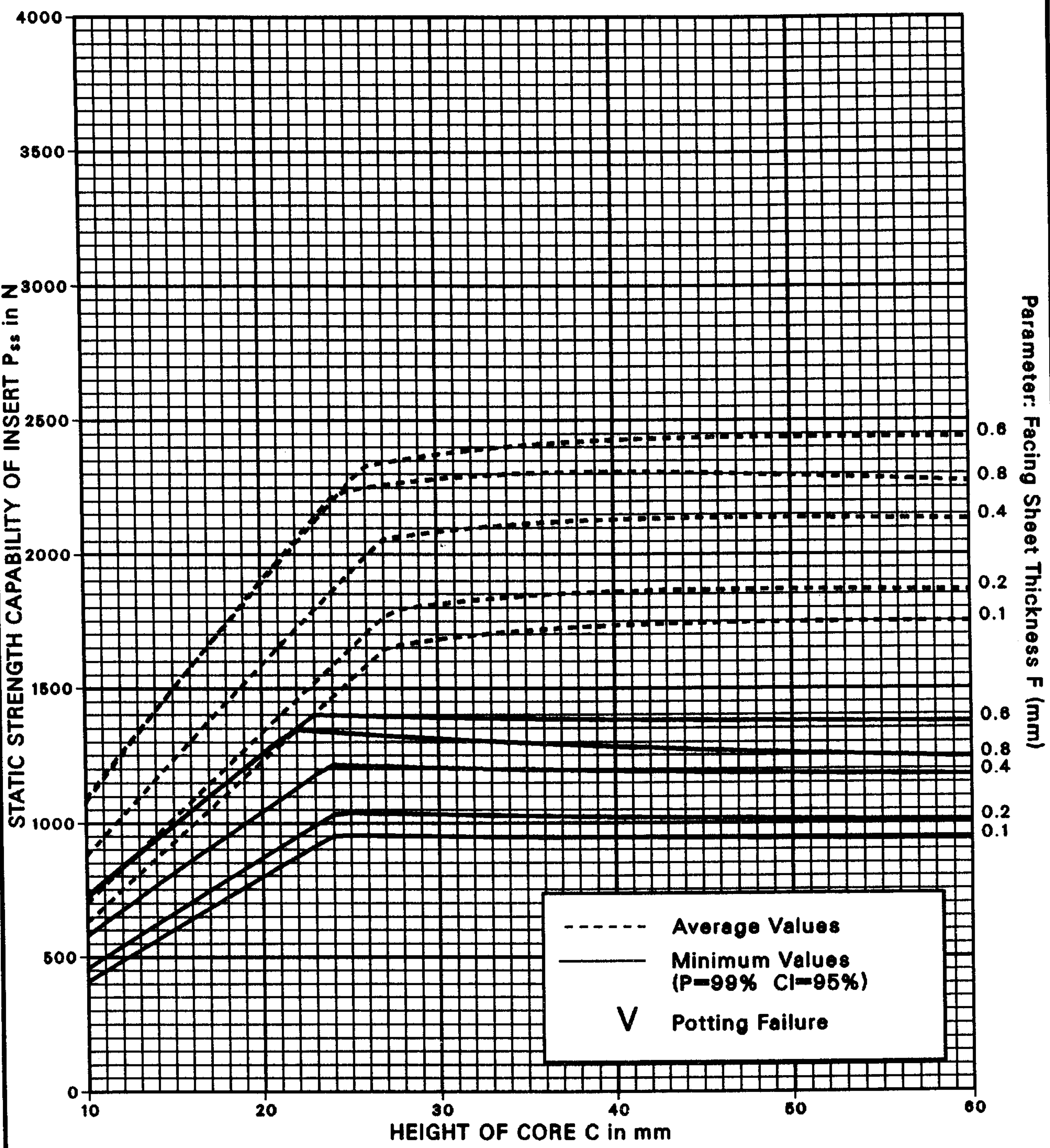


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Compression**

Insert Diameter: **17.5 mm**

Core : **3/16-5052-.0007**

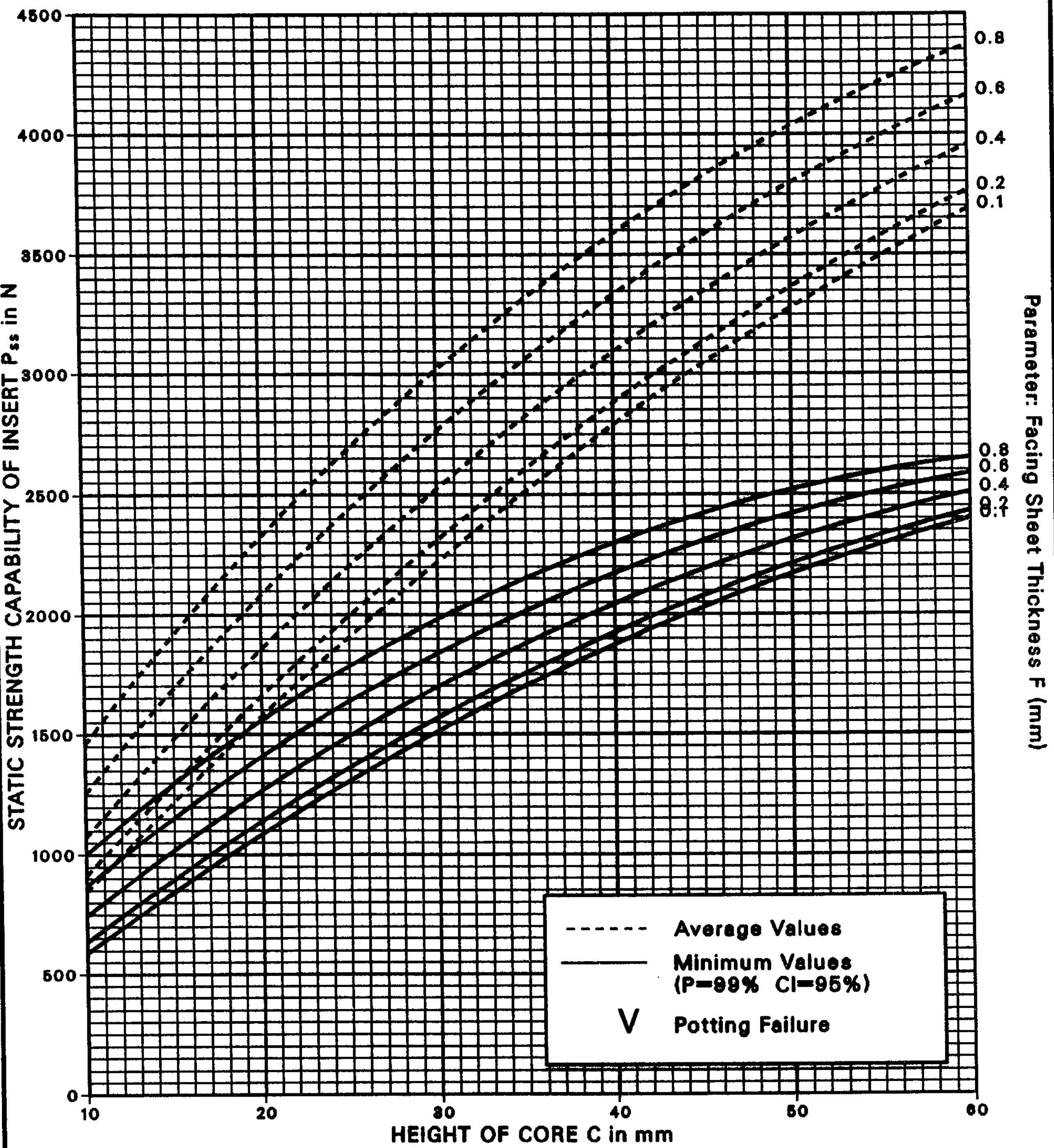


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Tension**

Insert Diameter: **22.5 mm**

Core : **3/16-5052-.0007**

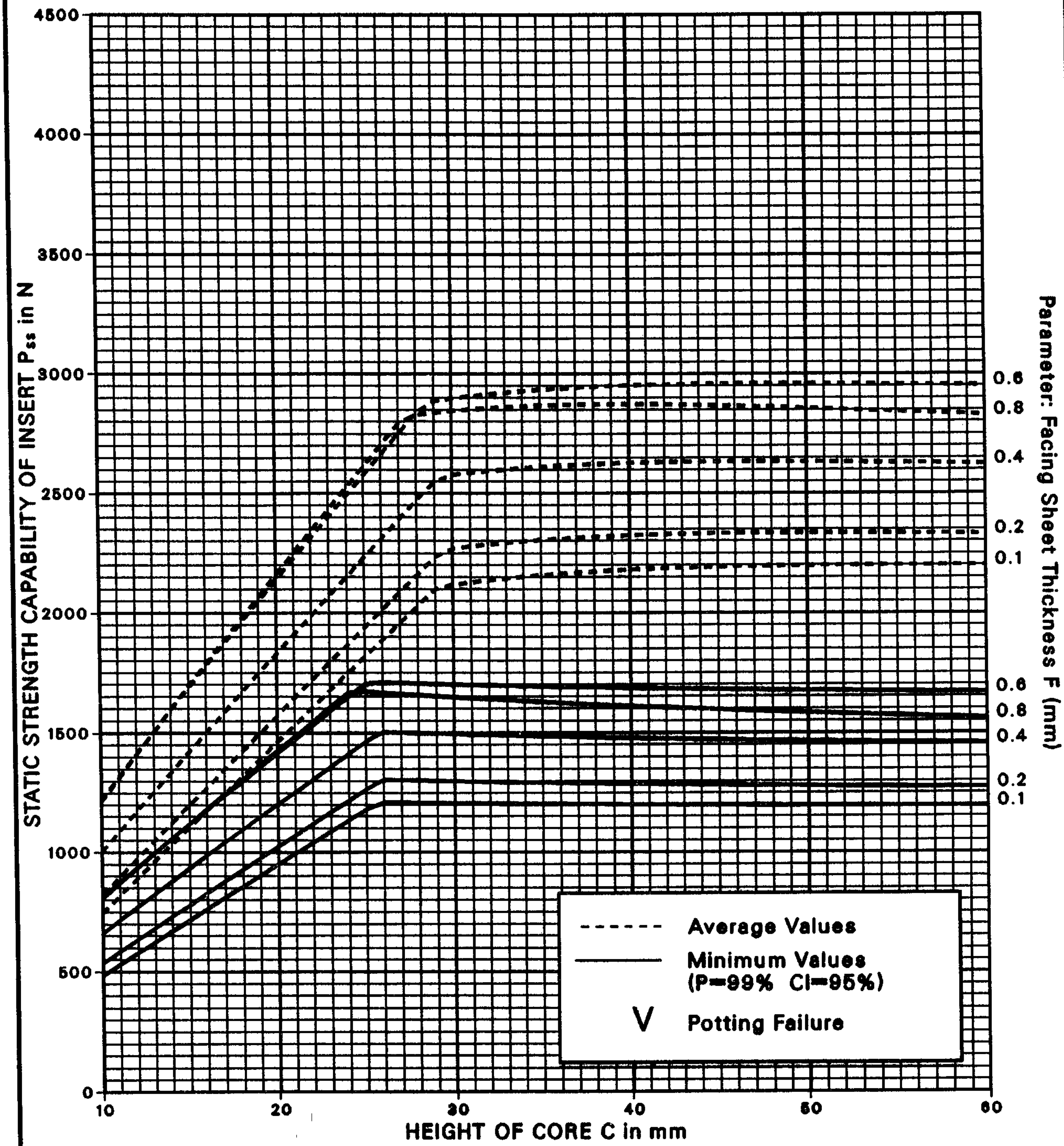


Insert Height h = 9 mm Facing Material AL 2024

Load : **Compression**

Insert Diameter: **22.5 mm**

Core : **3/16-5052-.0007**



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2. 3/16 – 5052 – 0.001 Core

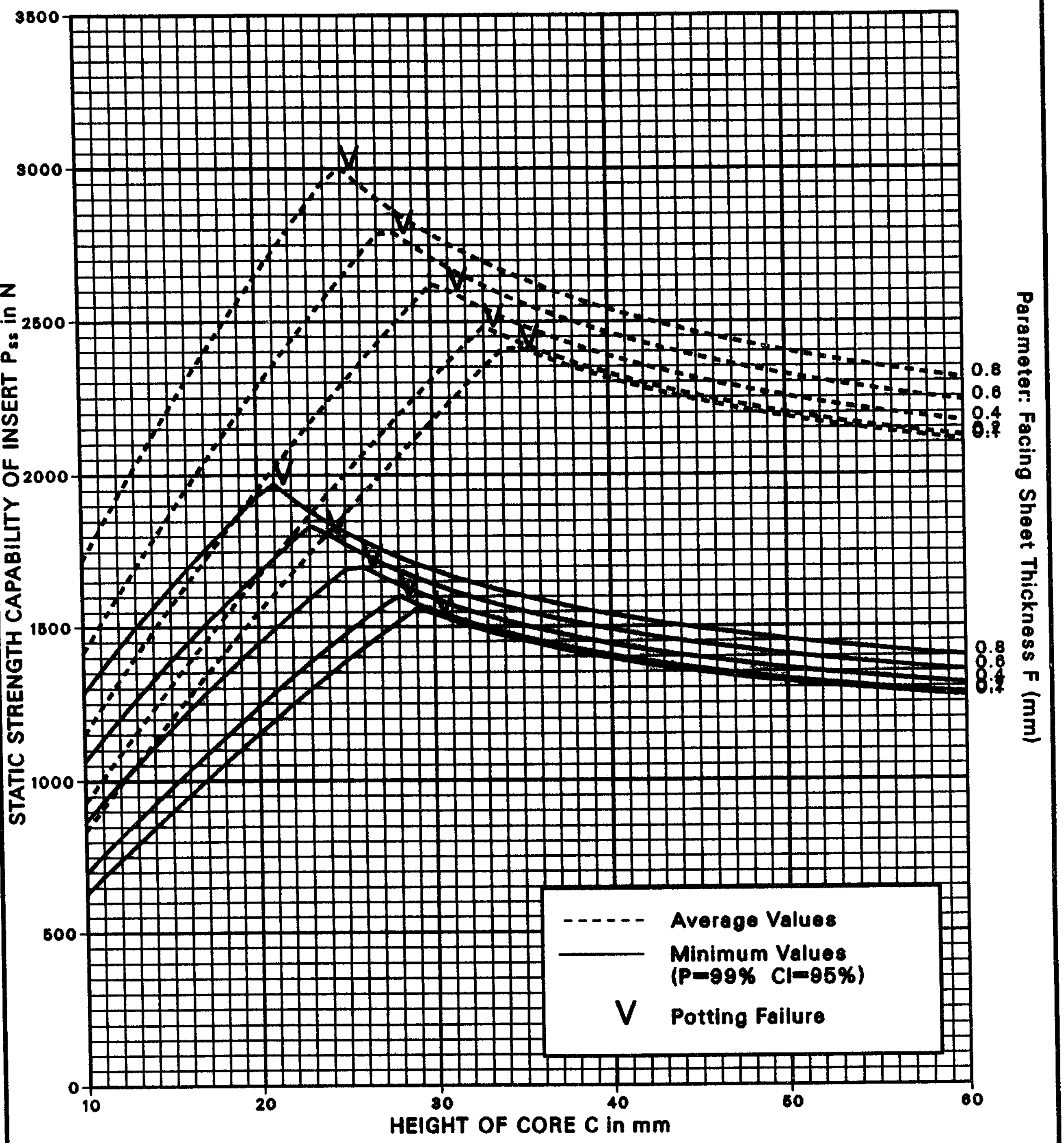
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **9.0 mm**

Core : **3/16-5052-.001**



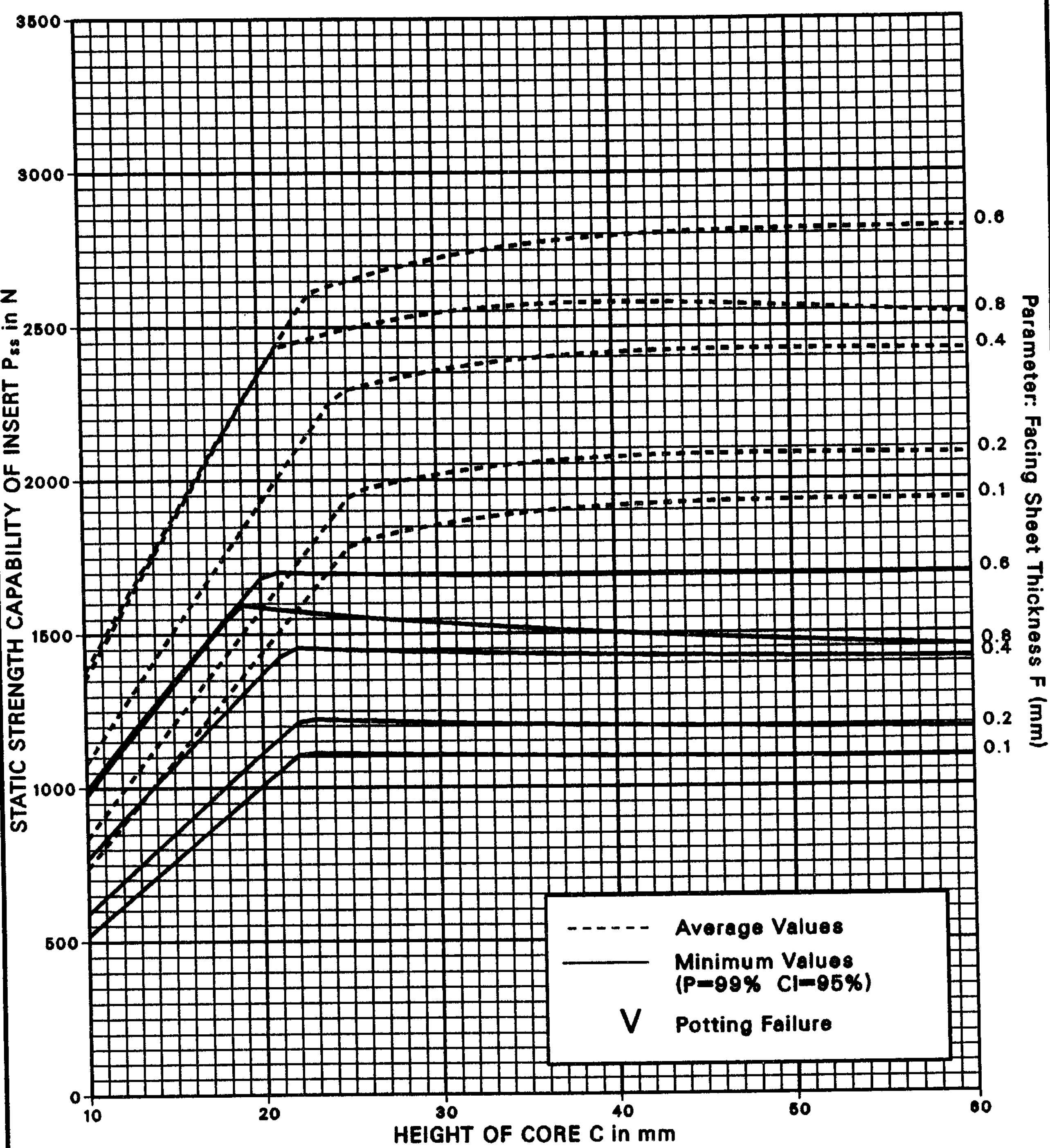
Version 2.0

Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 9.0 mm

Core : 3/16-5052-.001

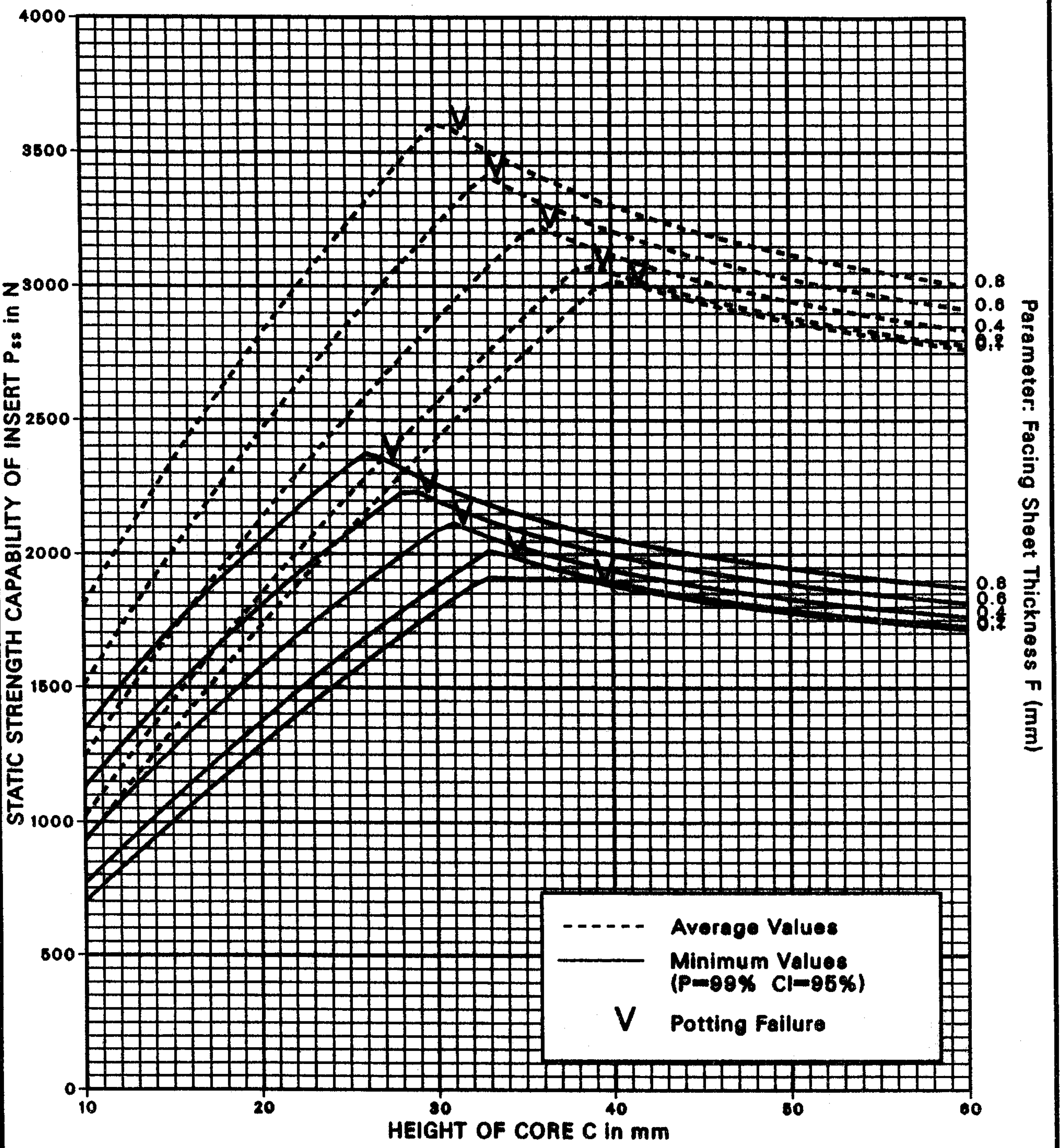


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **11.0 mm**

Core : **3/16-5052-.001**

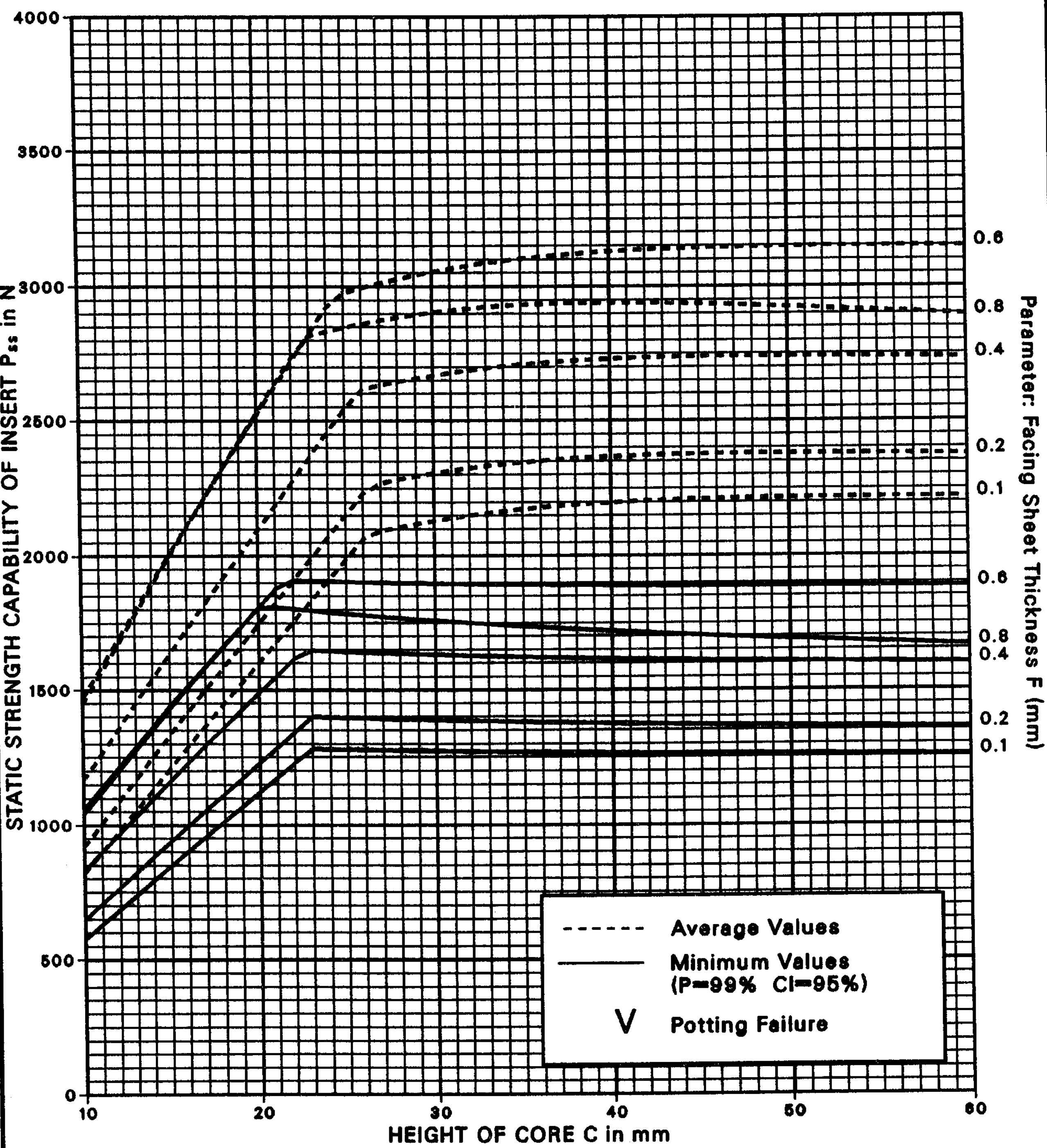


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Compression**

Insert Diameter: **11.0 mm**

Core : **3/16-5052-.001**



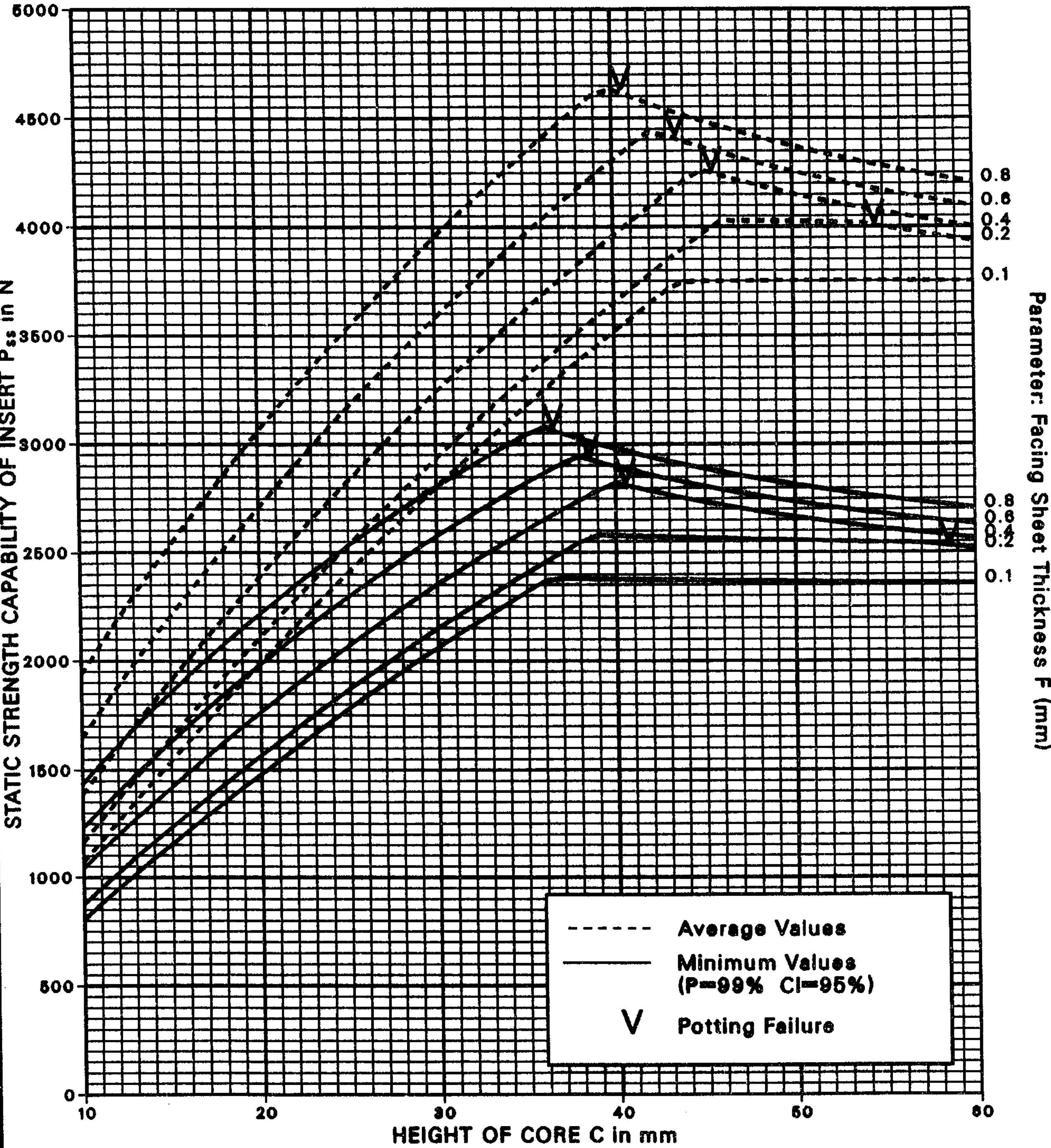
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **14.0 mm**

Core : **3/16-5052-.001**

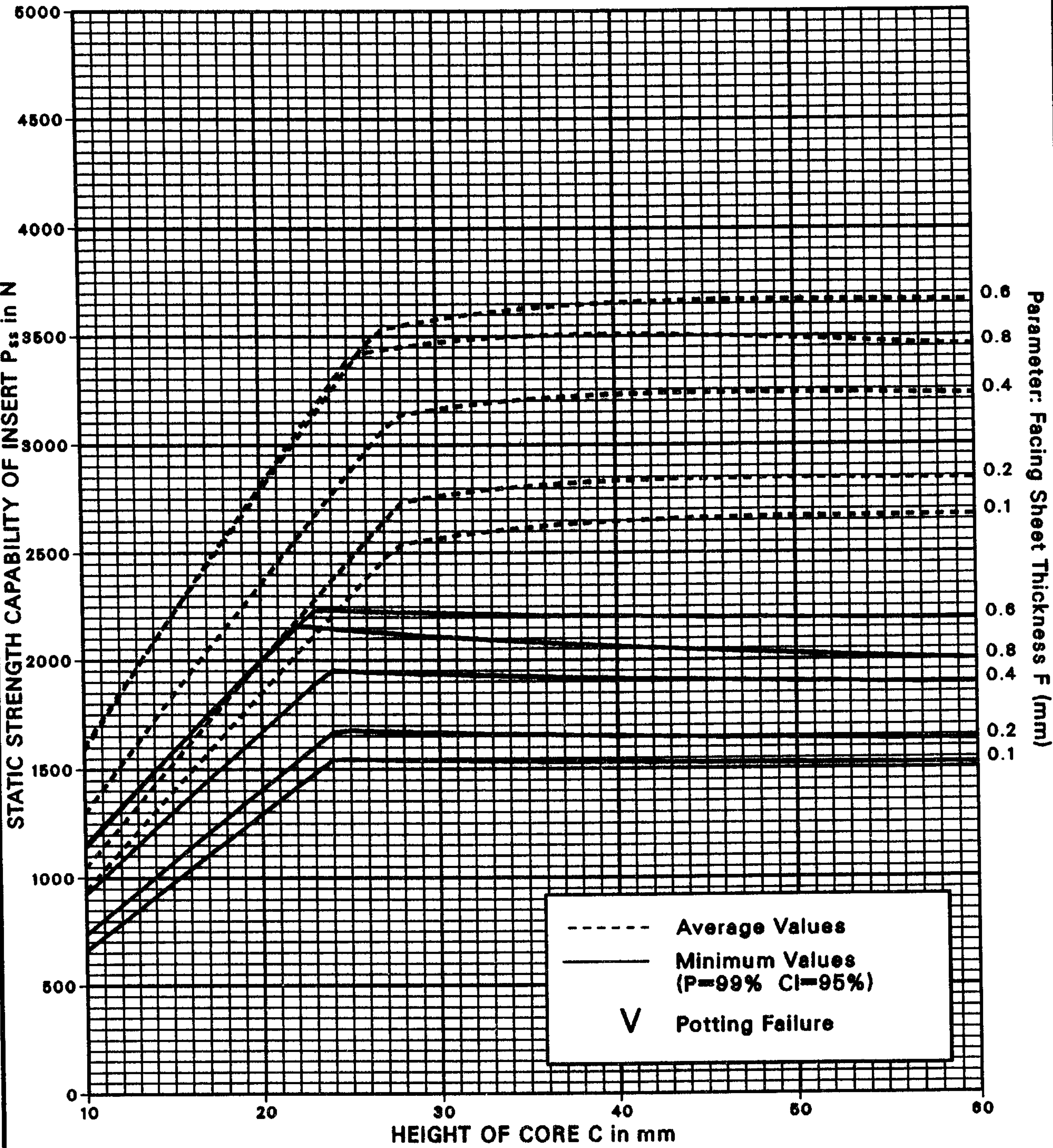


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 14.0 mm

Core : 3/16-5052-.001



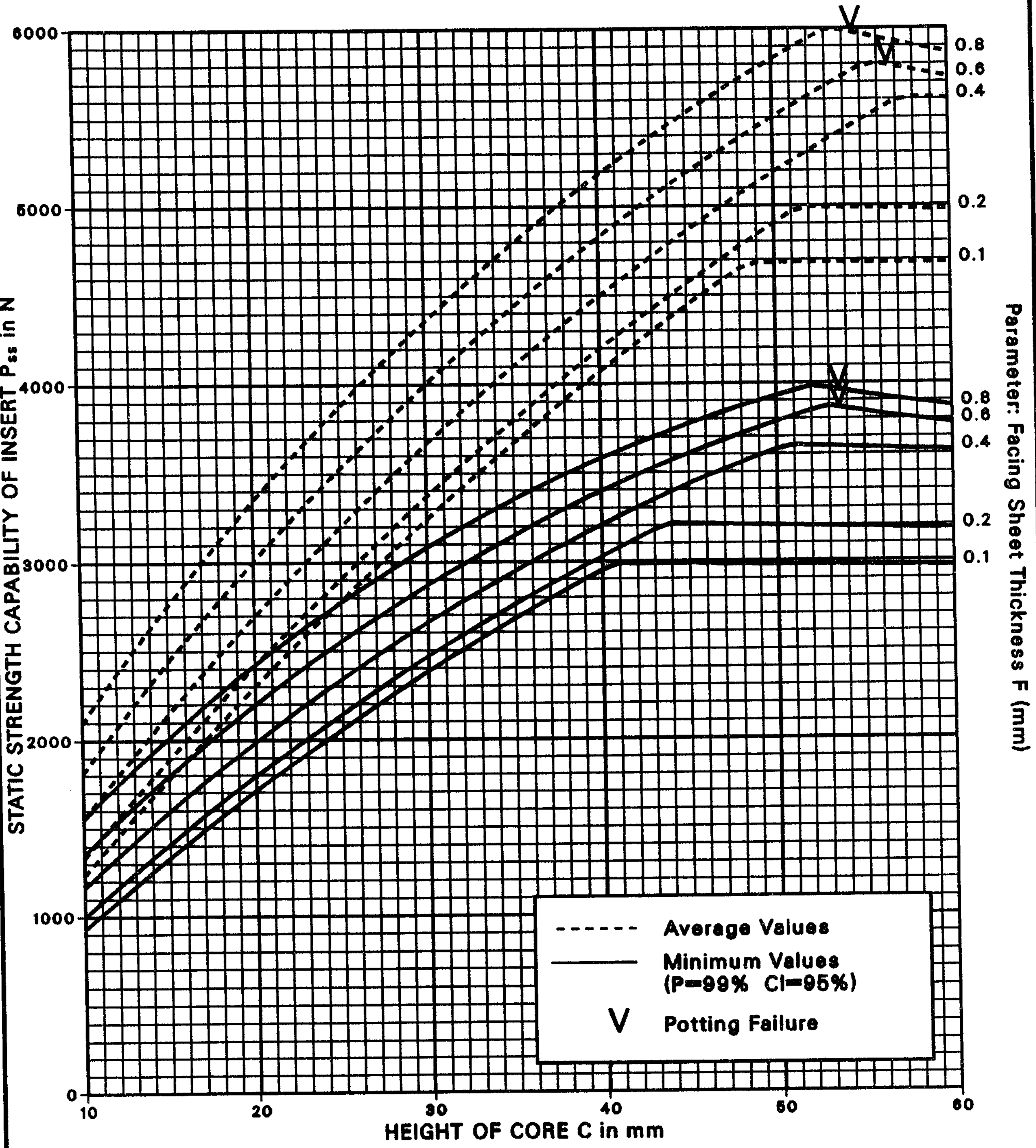
Insert Height h = 9 mm

Facing Material AL 2024

Load : Tension

Insert Diameter: 17.5 mm

Core : 3/16-5052-.001

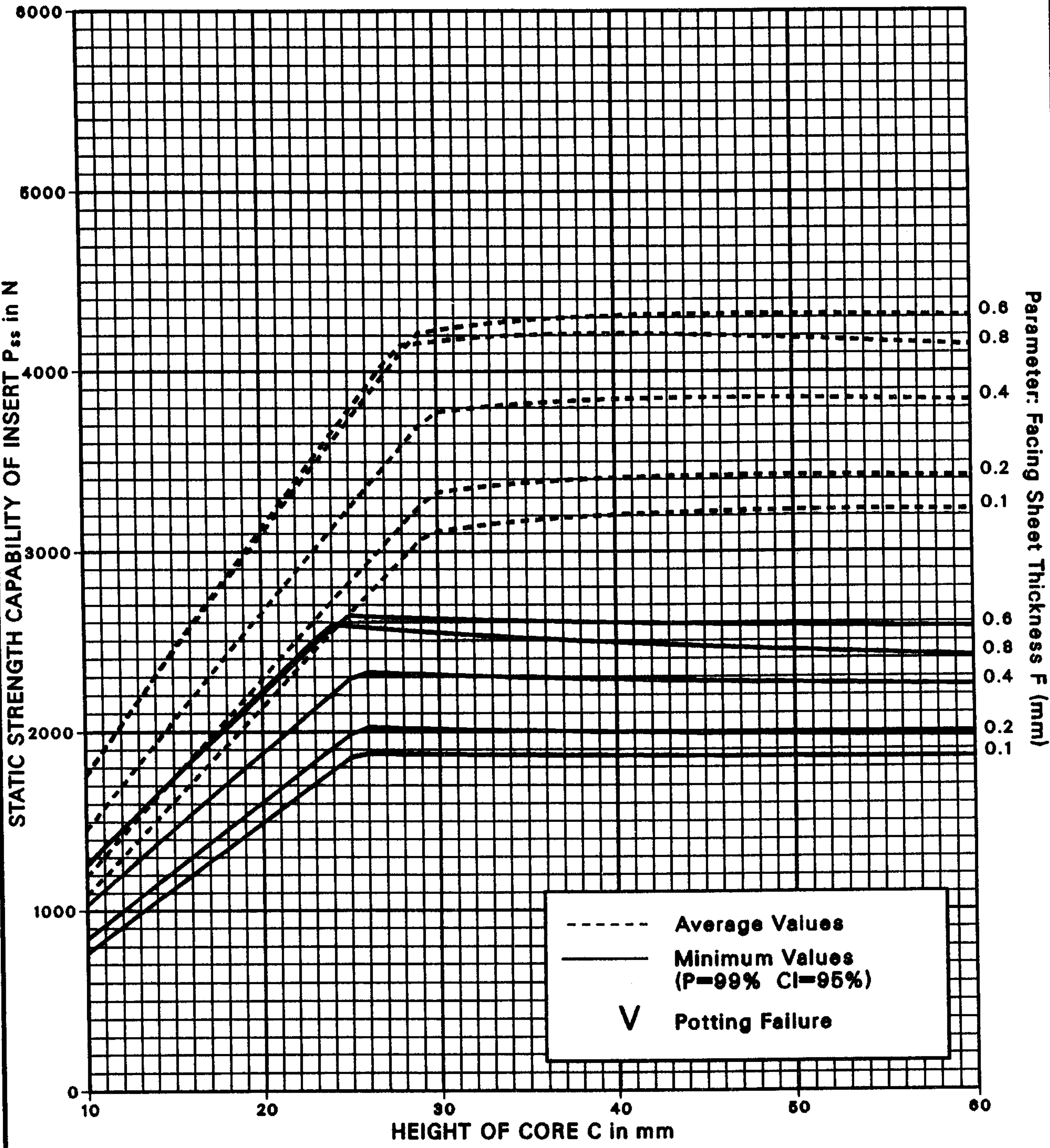


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Compression**

Insert Diameter: **17.5 mm**

Core : **3/16-5052-.001**

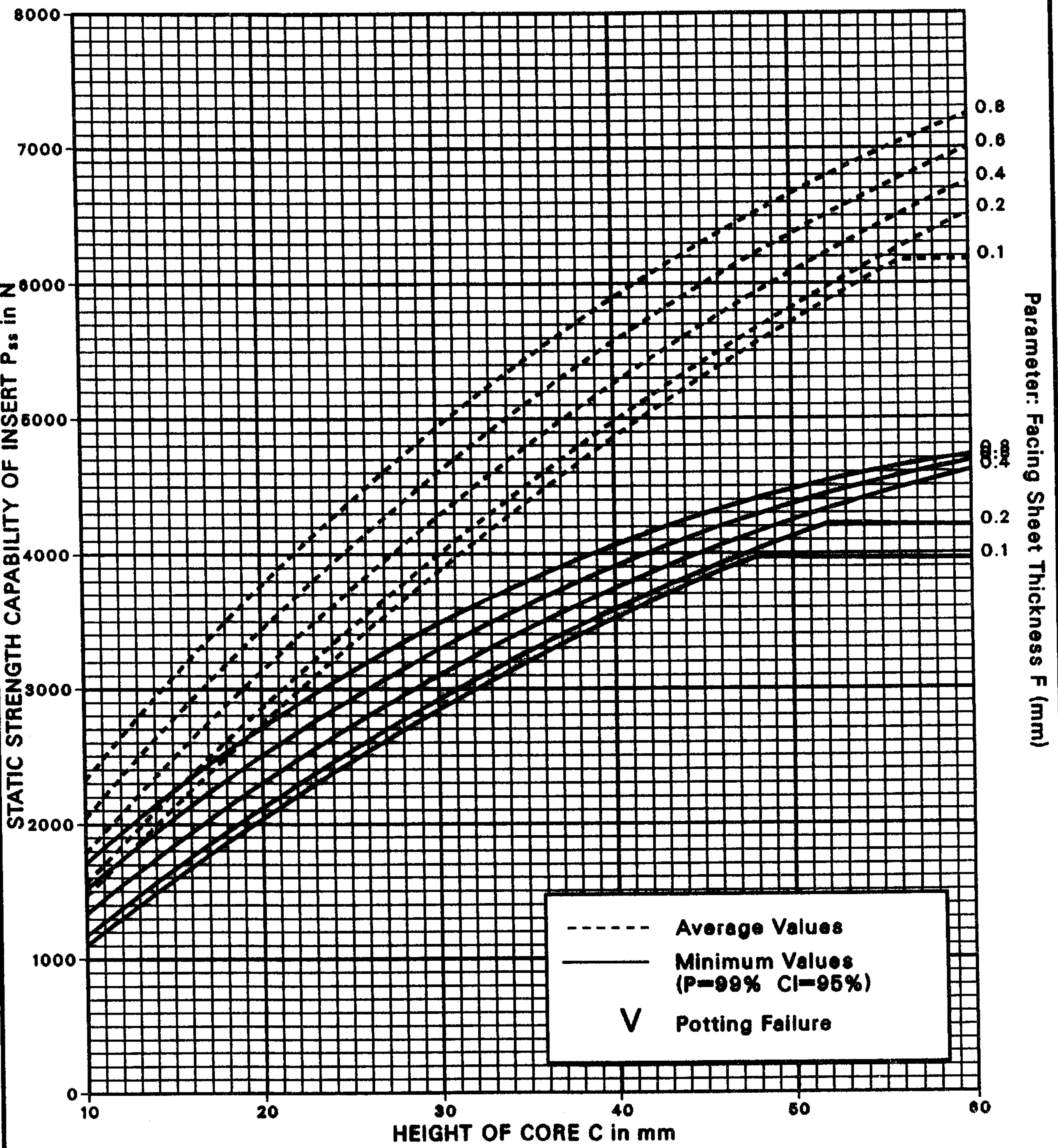


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **22.5 mm**

Core : **3/16-5052-.001**

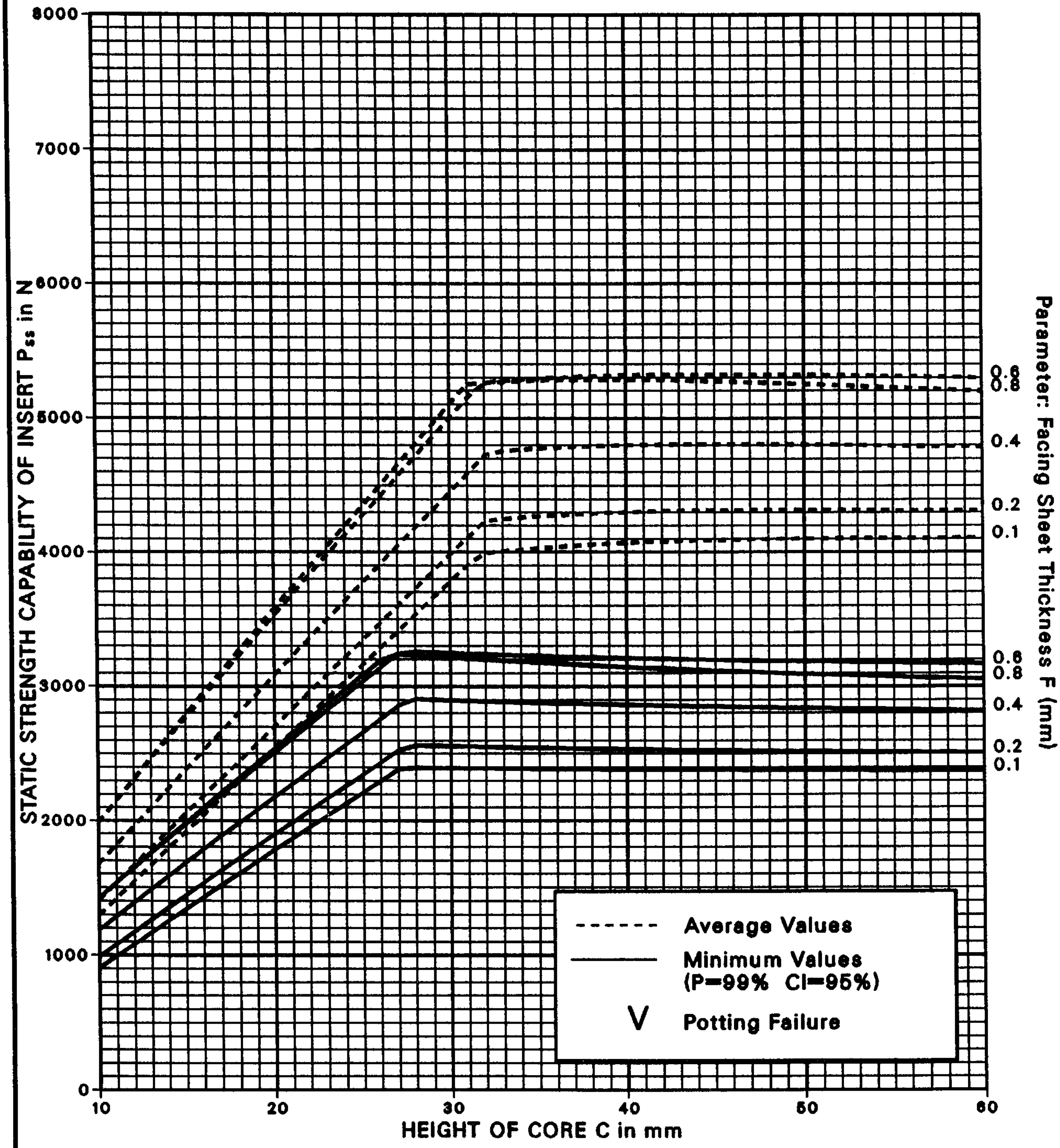


Insert Height h = 9 mm Facing Material AL 2024

Load : **Compression**

Insert Diameter: **22.5 mm**

Core : **3/16-5052-.001**



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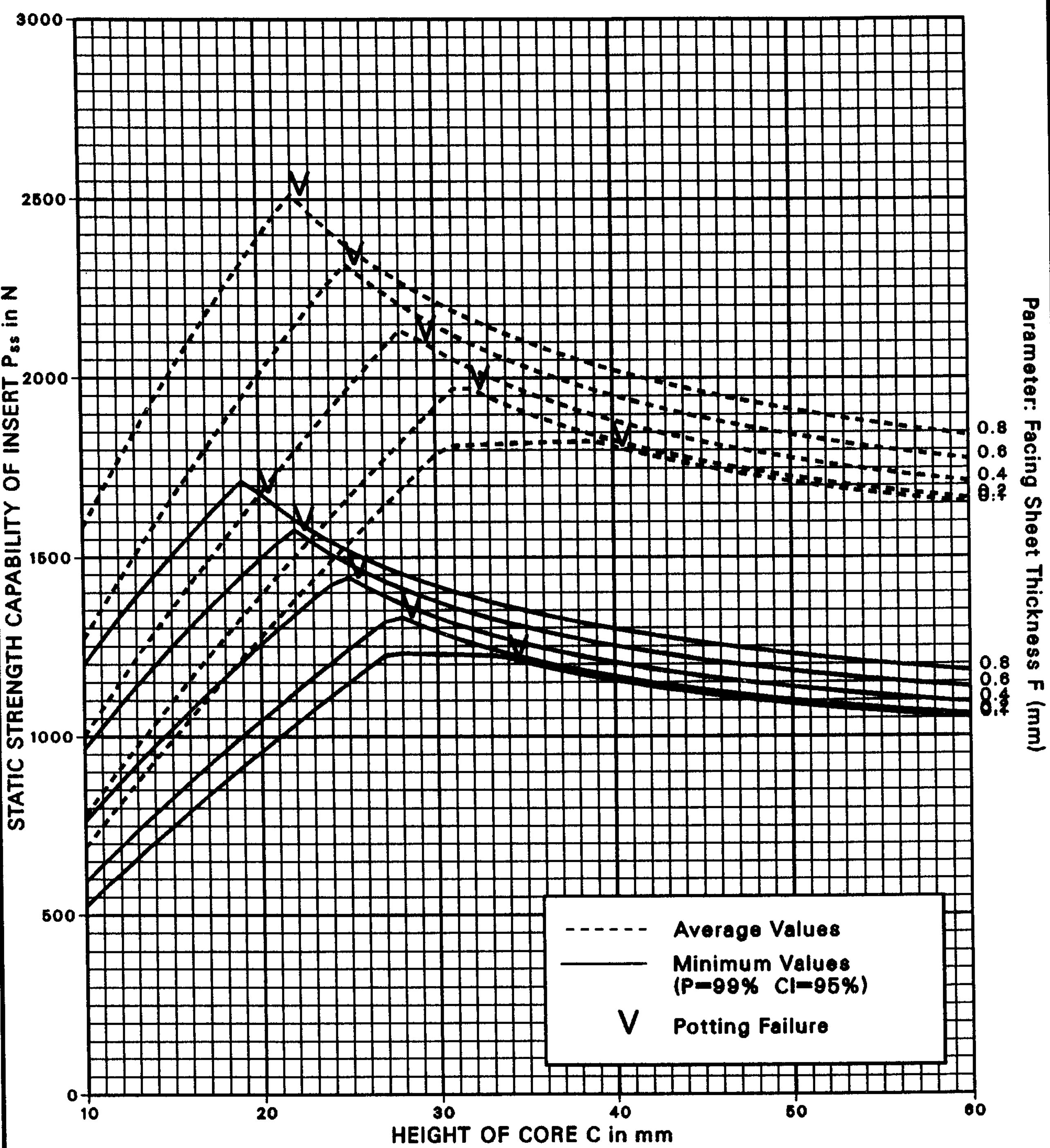
3. 1/8 – 5052 – 0.0007 Core

Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **9.0 mm**

Core : **1/8-5052-.0007**

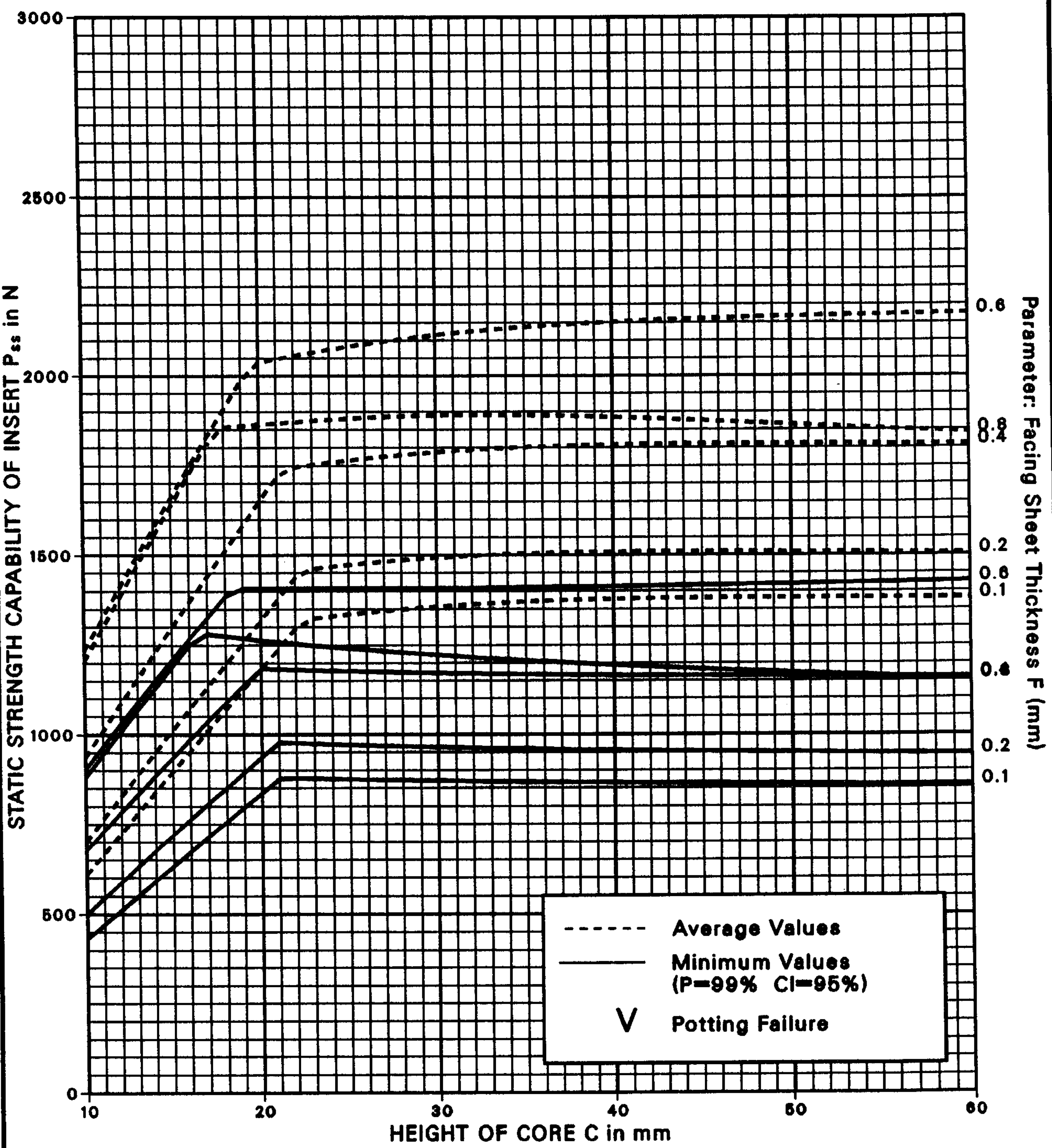


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Compression**

Insert Diameter: **9.0 mm**

Core : **1/8-5052-.0007**

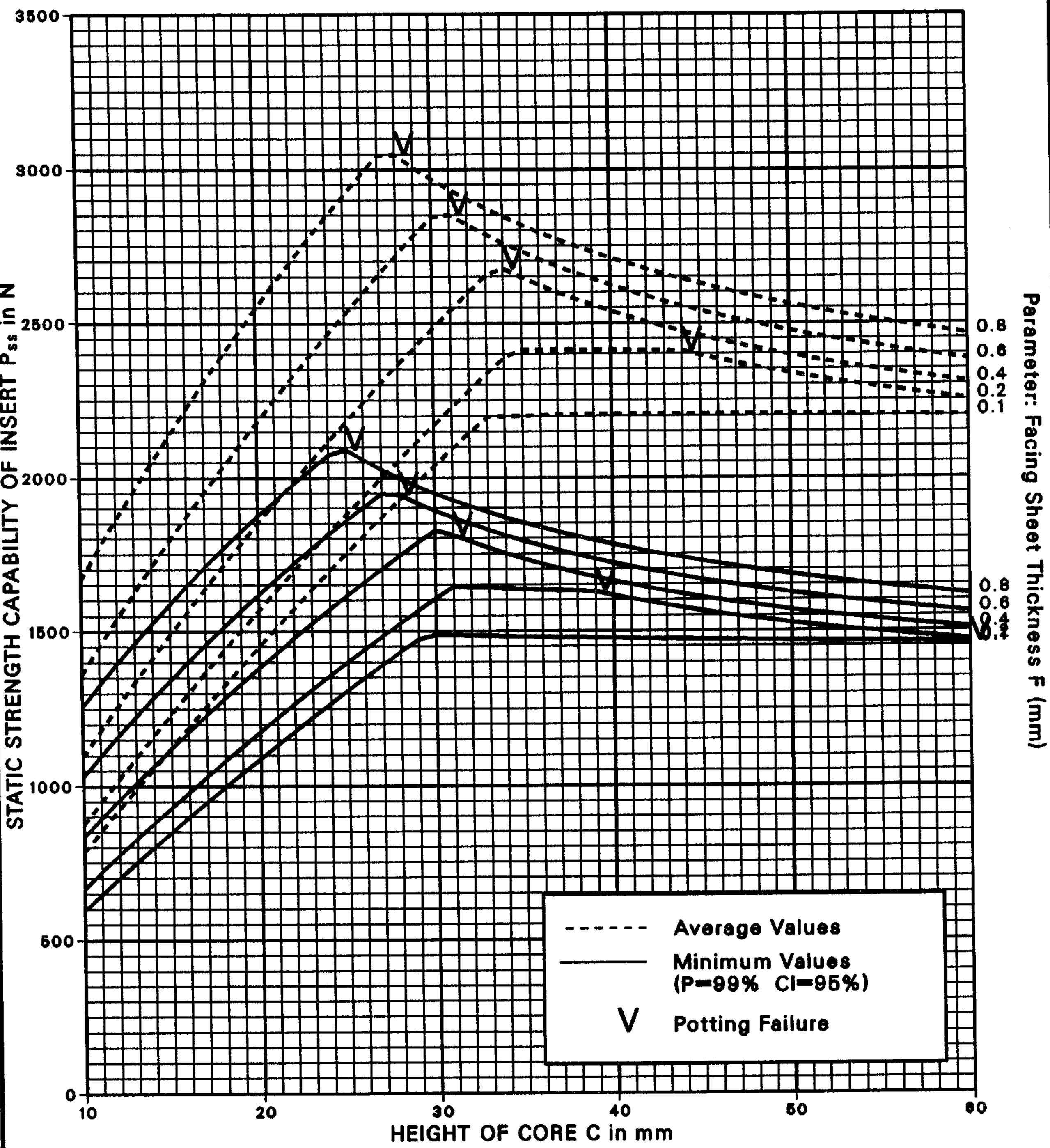


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **11.0 mm**

Core : **1/8-5052-.0007**

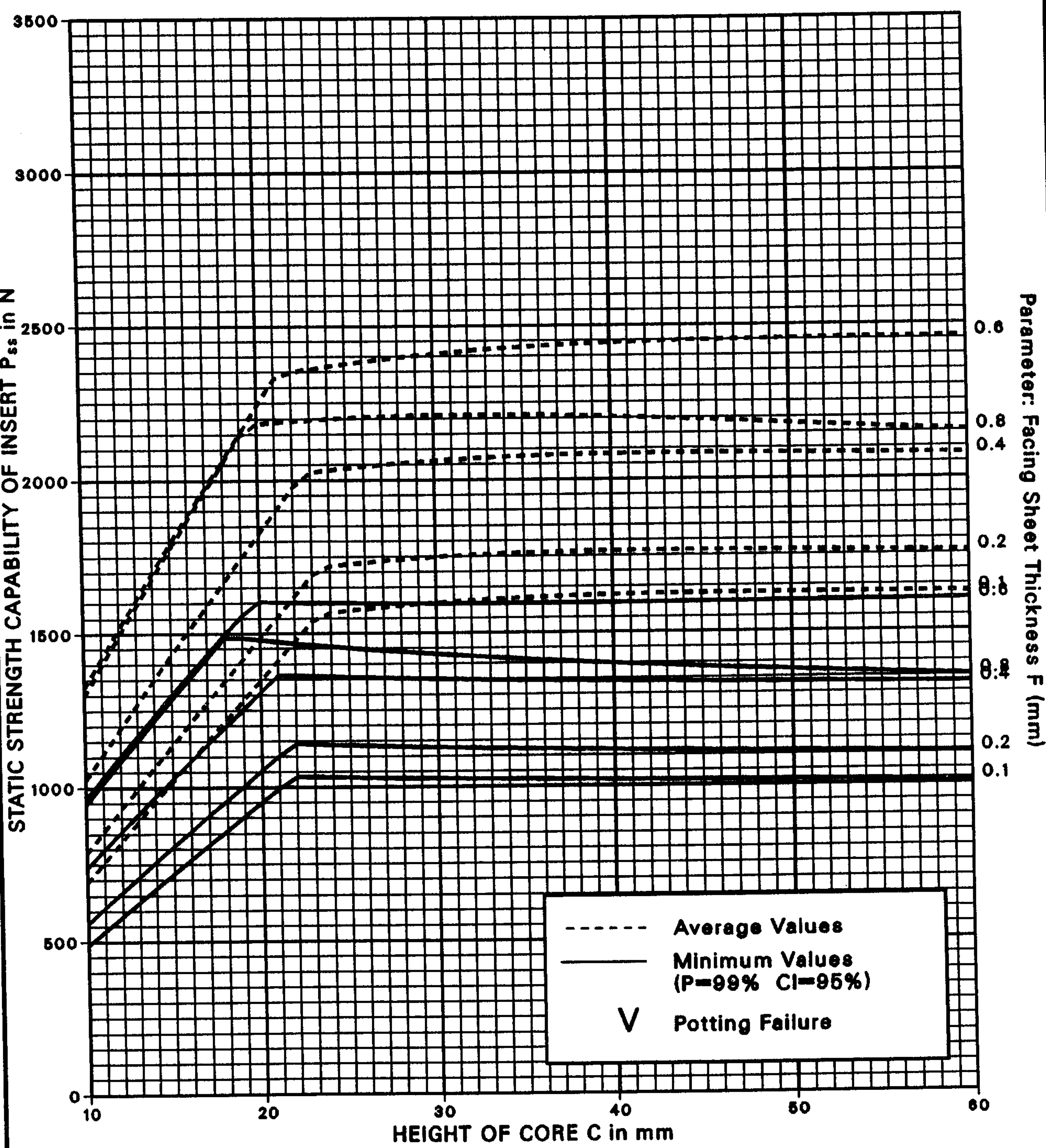


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 11.0 mm

Core : 1/8-5052-.0007

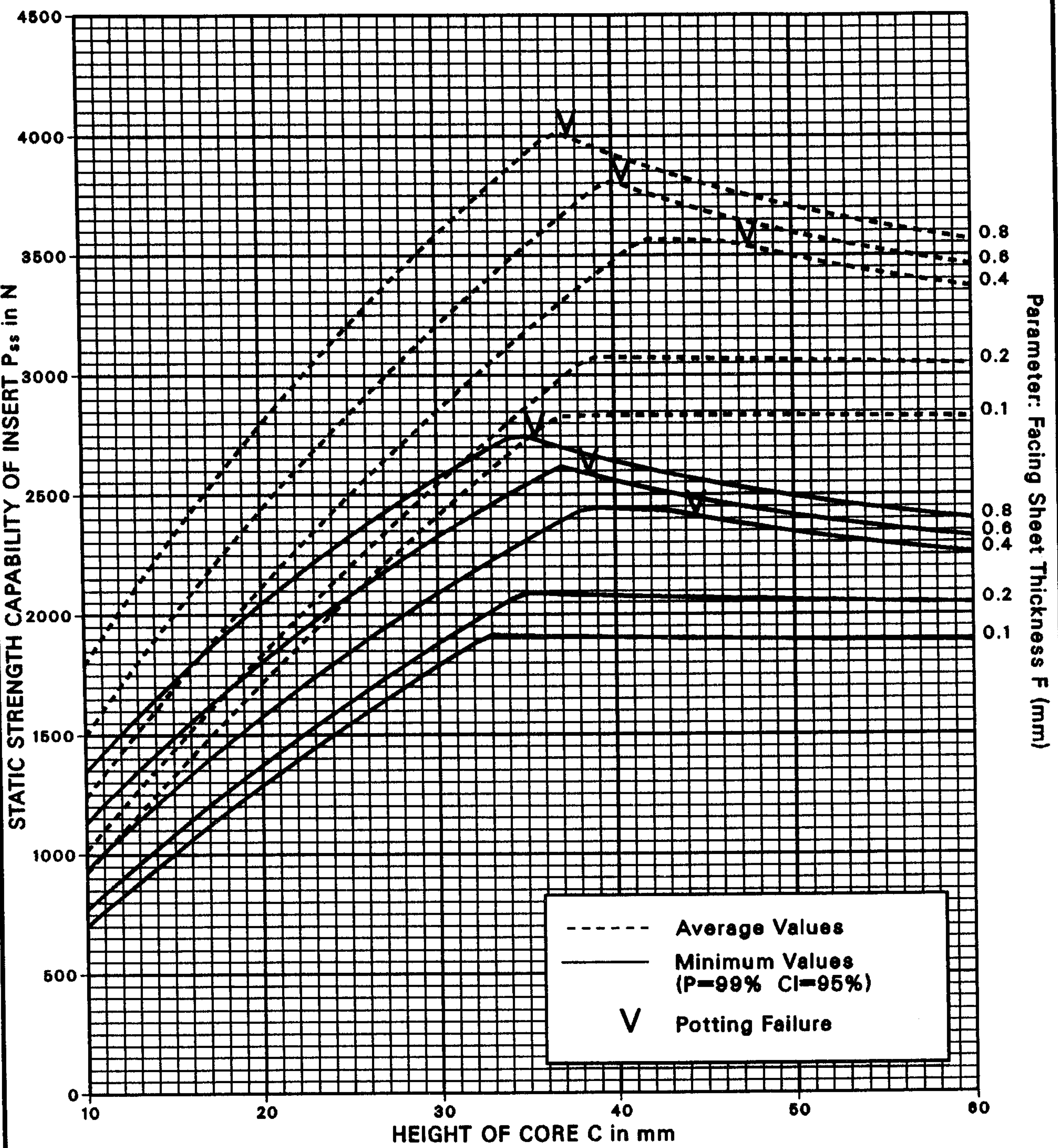


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **14.0 mm**

Core : **1/8-5052-.0007**

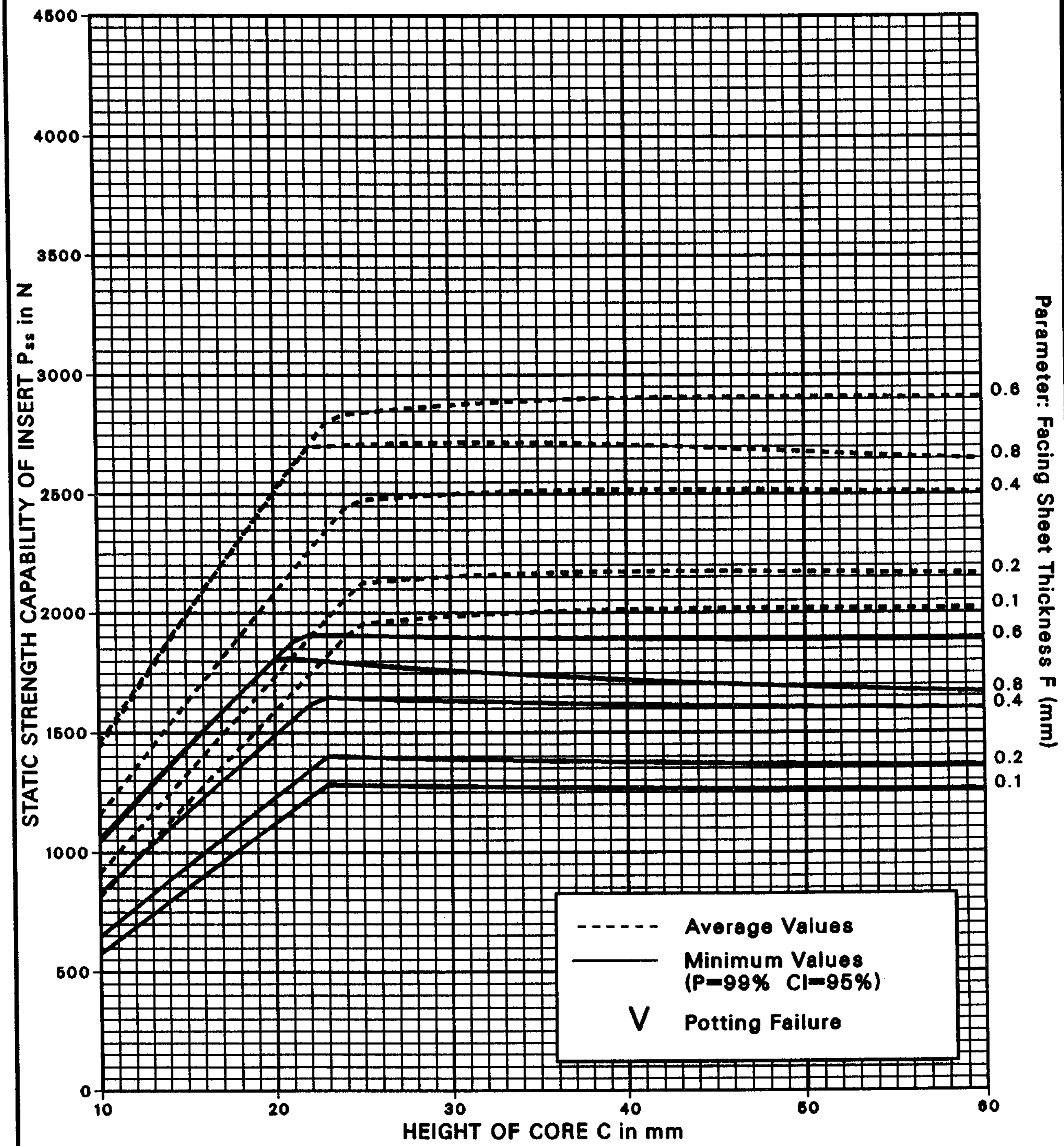


Insert Height h = 9 mm Facing Material AL 2024

Load : **Compression**

Insert Diameter: **14.0 mm**

Core : **1/8-5052-.0007**

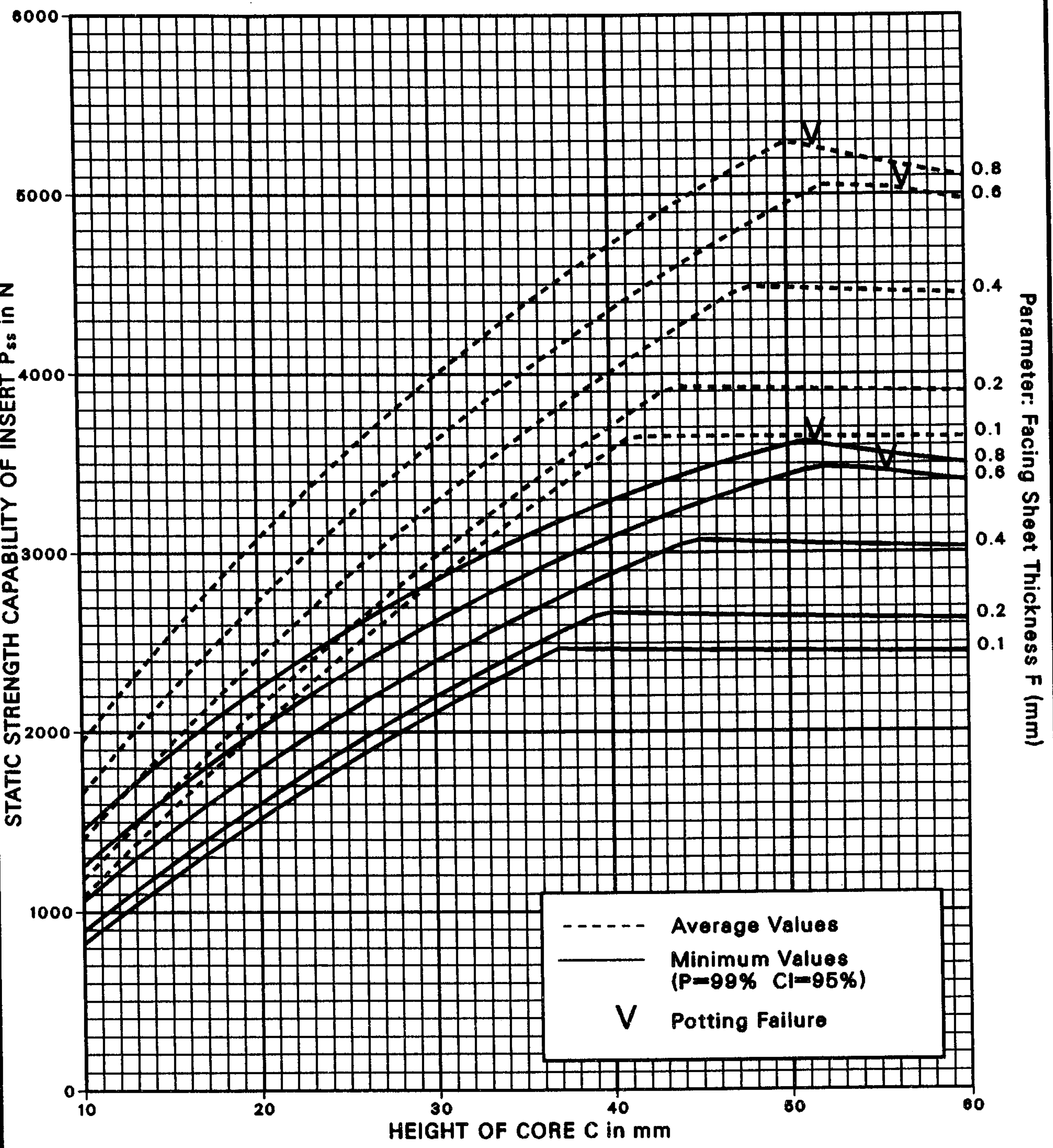


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **17.5 mm**

Core : **1/8-5052-.0007**

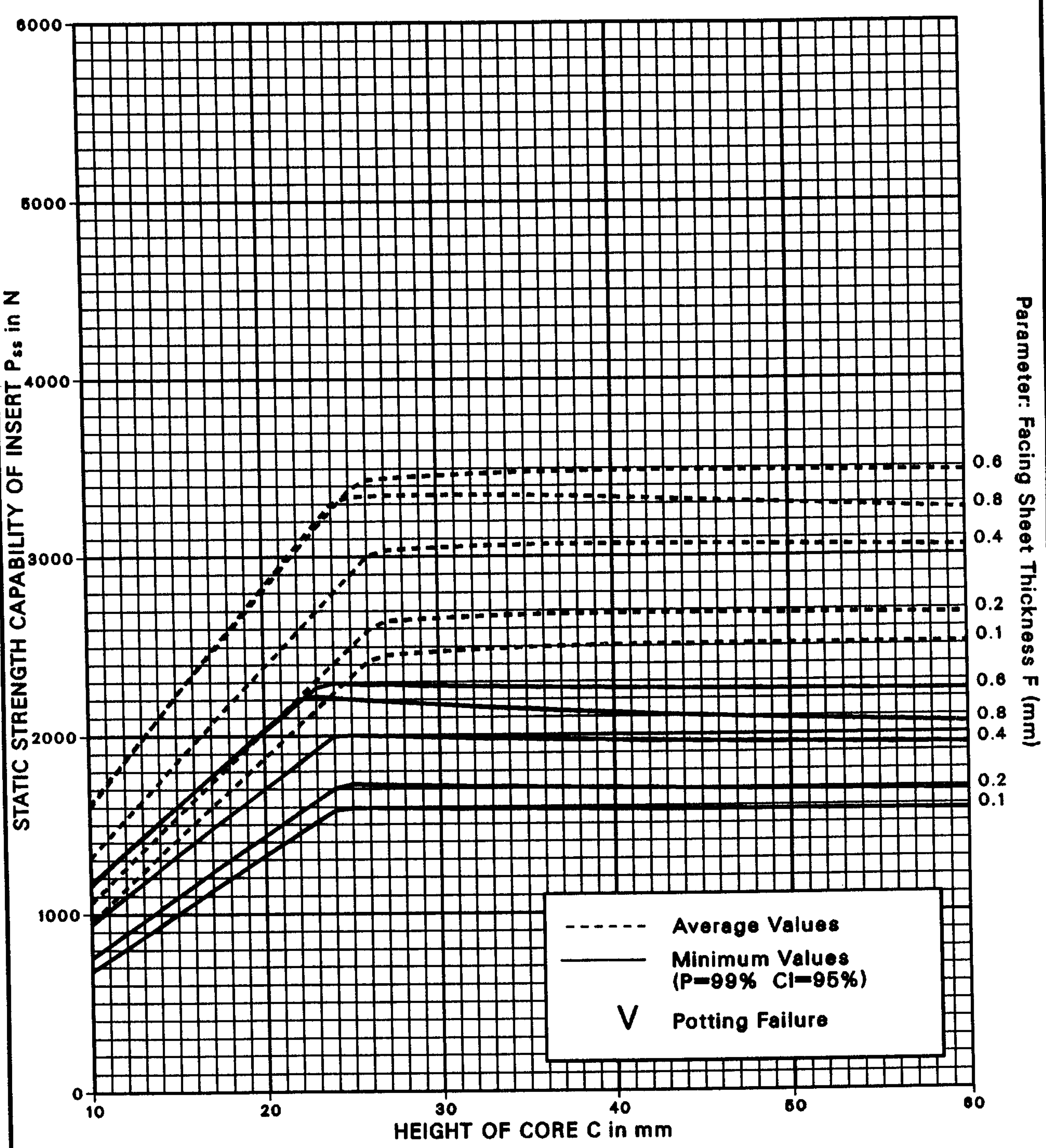


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 17.5 mm

Core : 1/8-5052-.0007

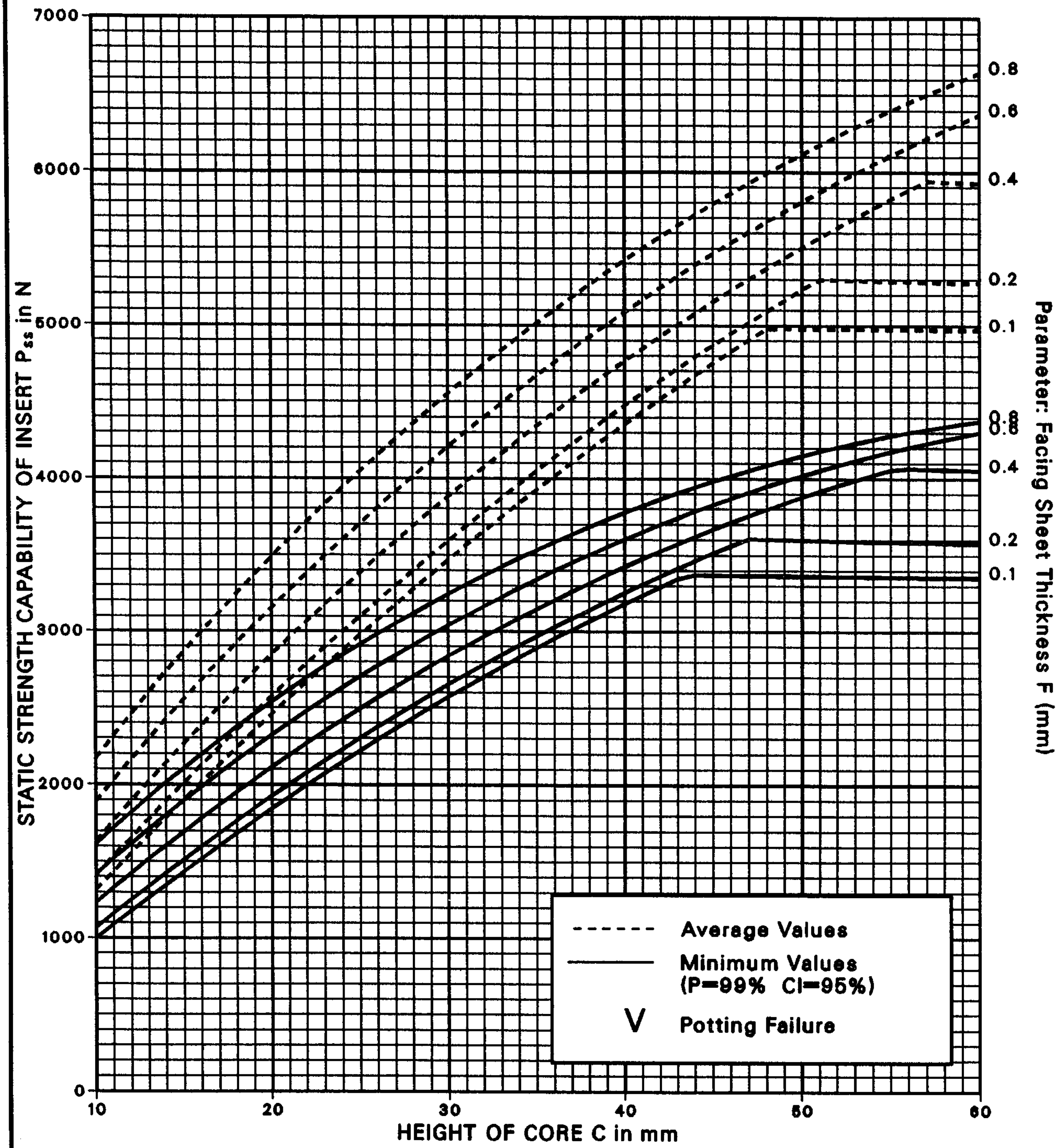


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **22.5 mm**

Core : **1/8-5052-.0007**

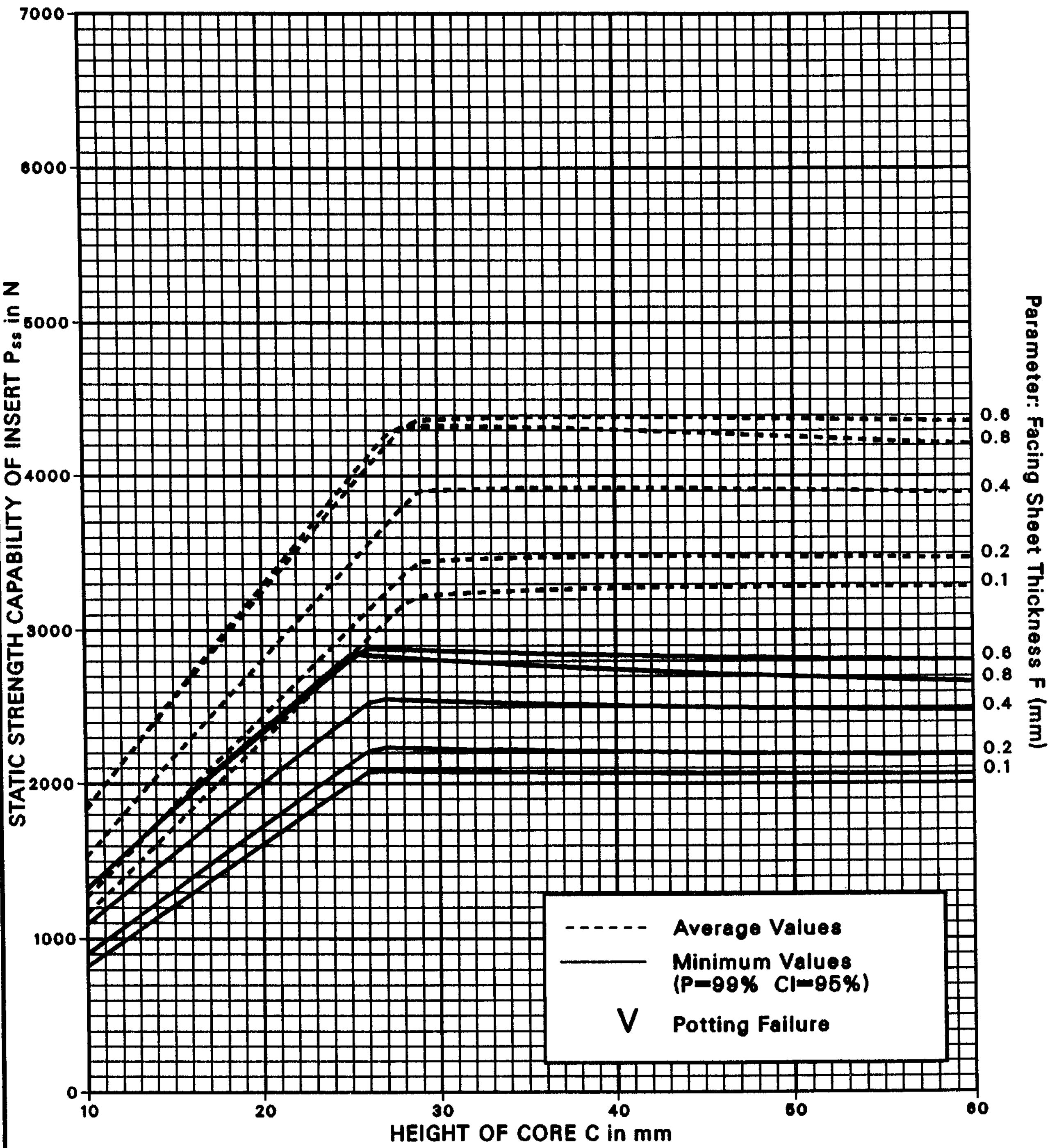


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 22.5 mm

Core : 1/8-5052-.0007



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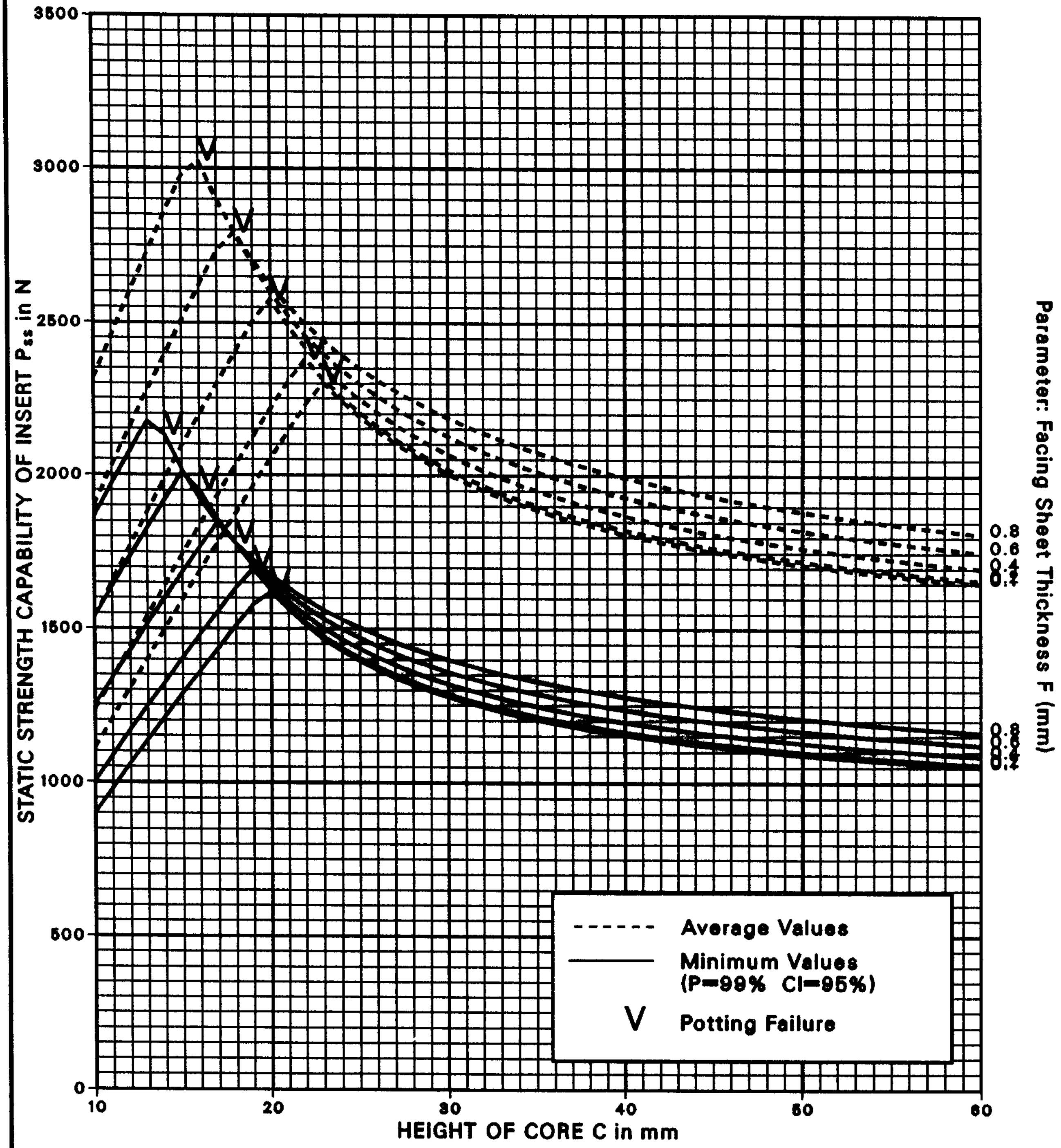
4. 1/8 – 5052 – 0.001 Core

Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **9.0 mm**

Core : **1/8-5052-.001**

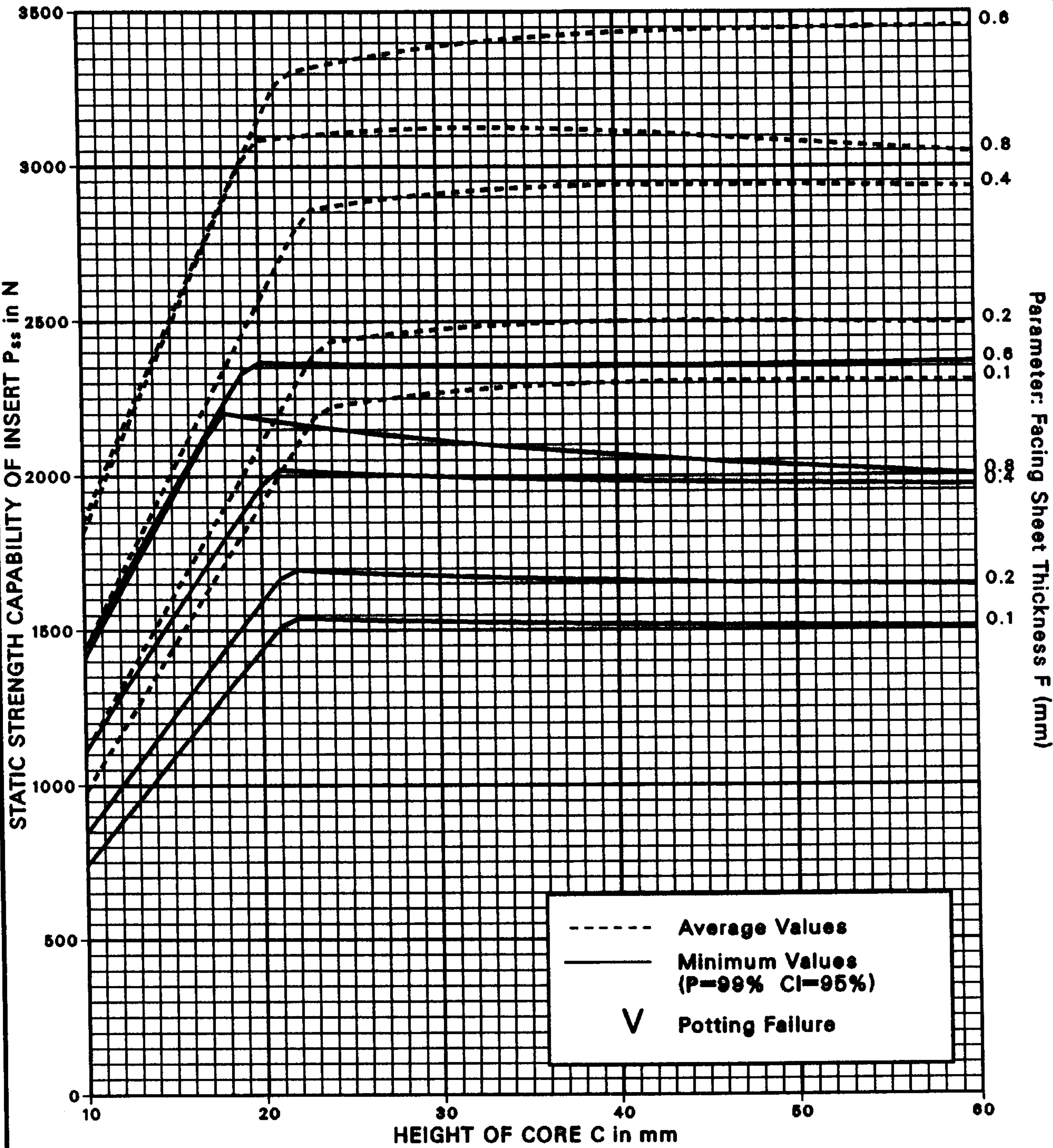


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 9.0 mm

Core : 1/8-5052-.001

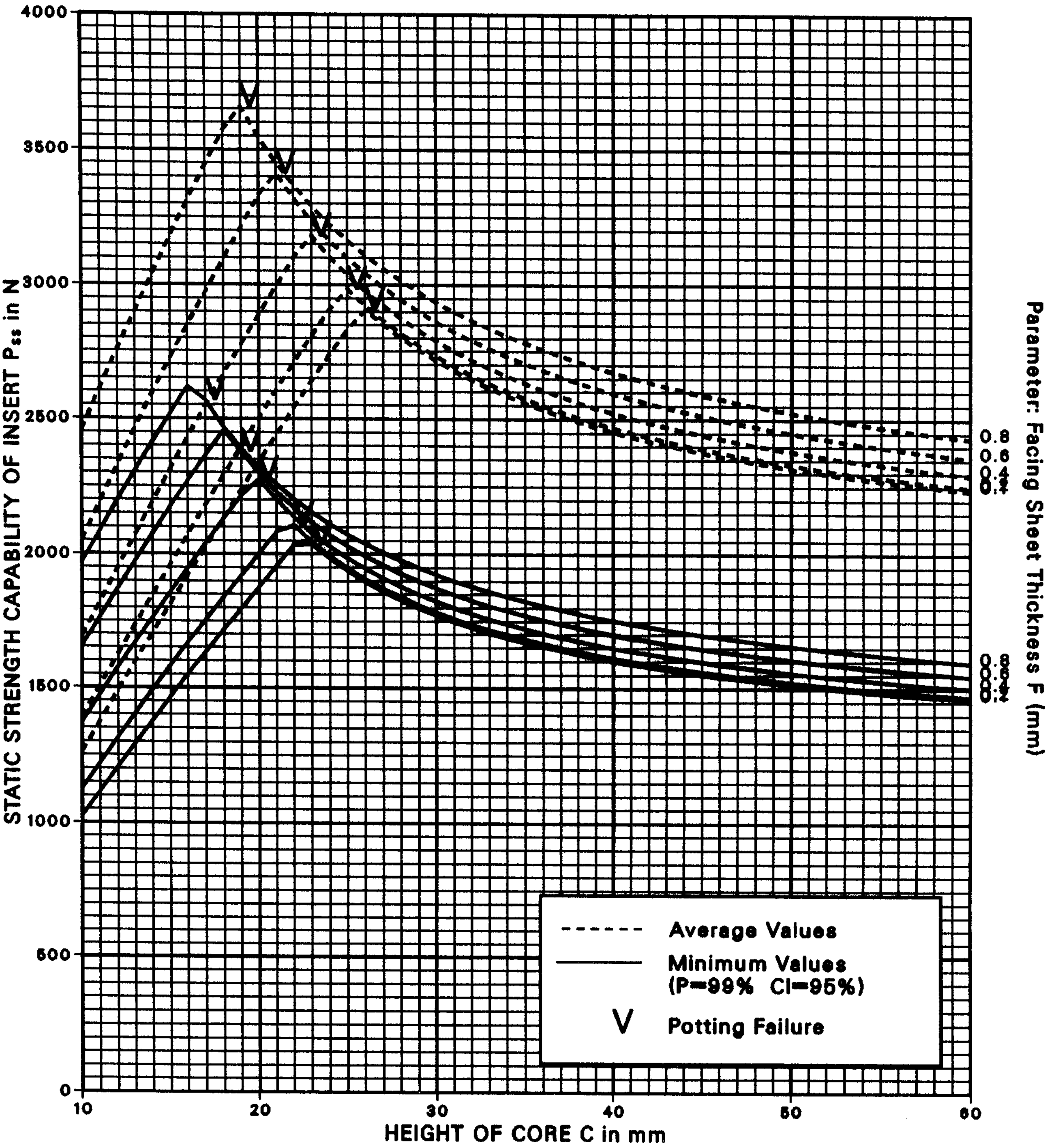


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **11.0 mm**

Core : **1/8-5052-.001**

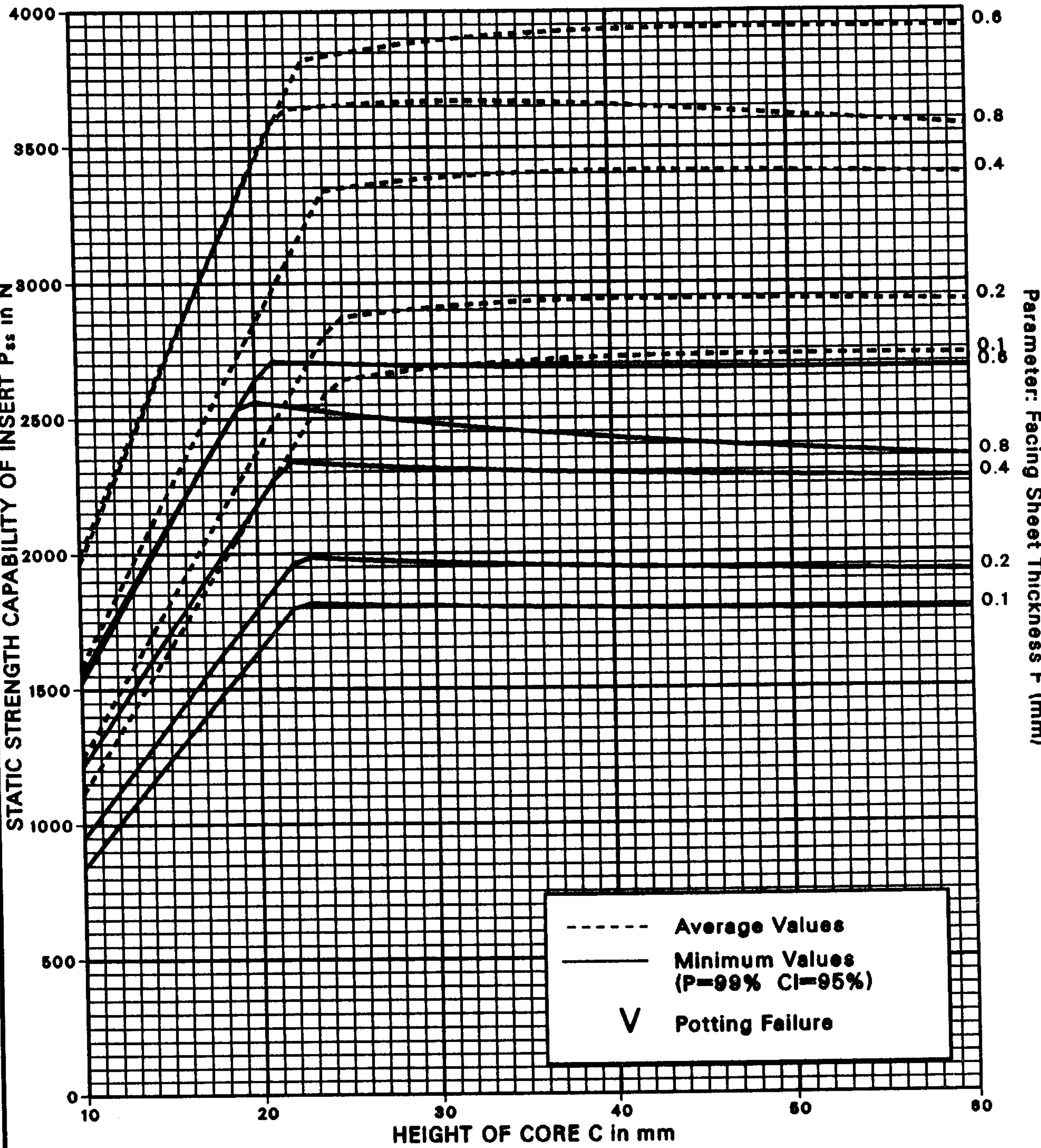


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 11.0 mm

Core : 1/8-5052-.001

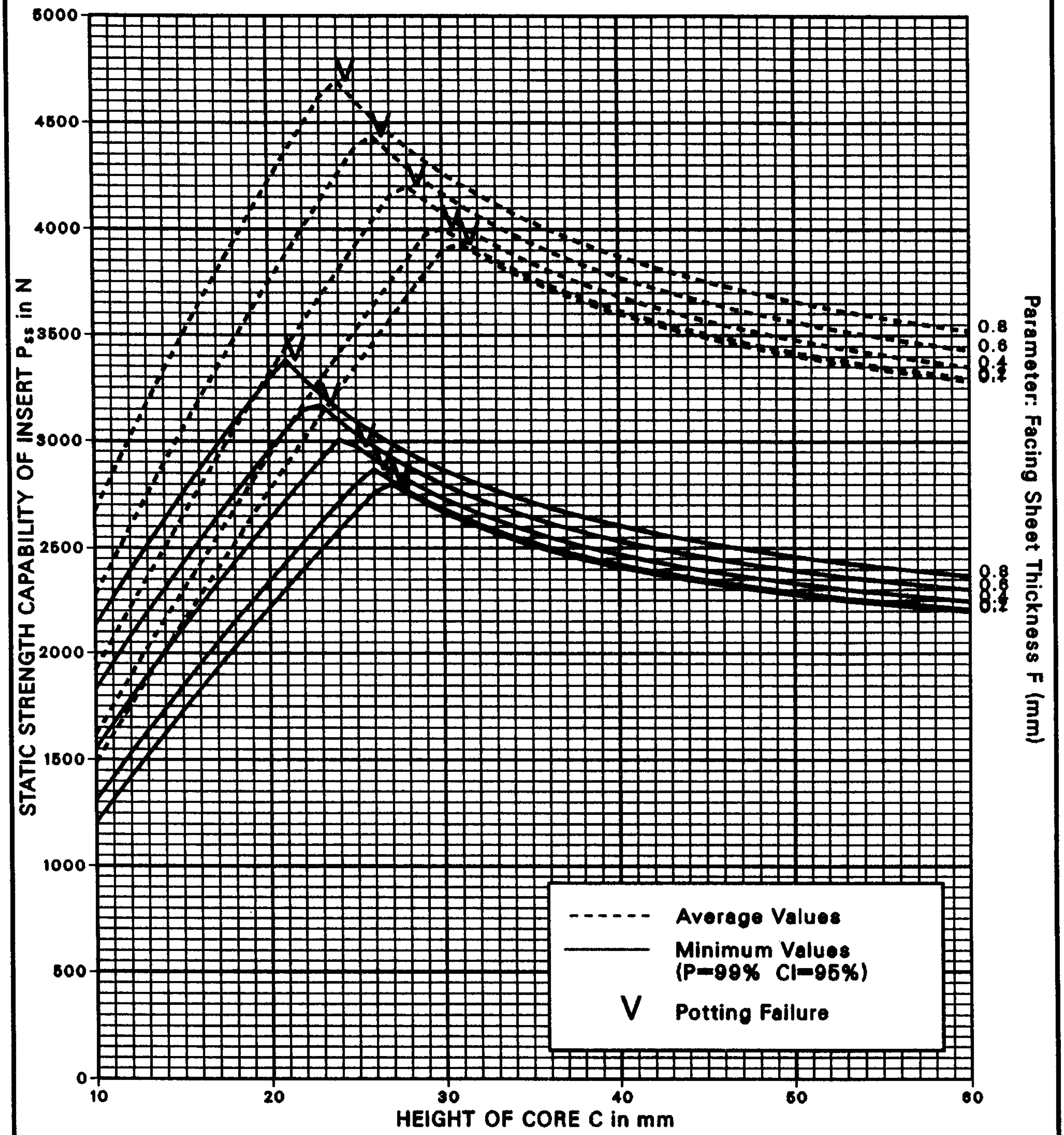


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **14.0 mm**

Core : **1/8-5052-.001**

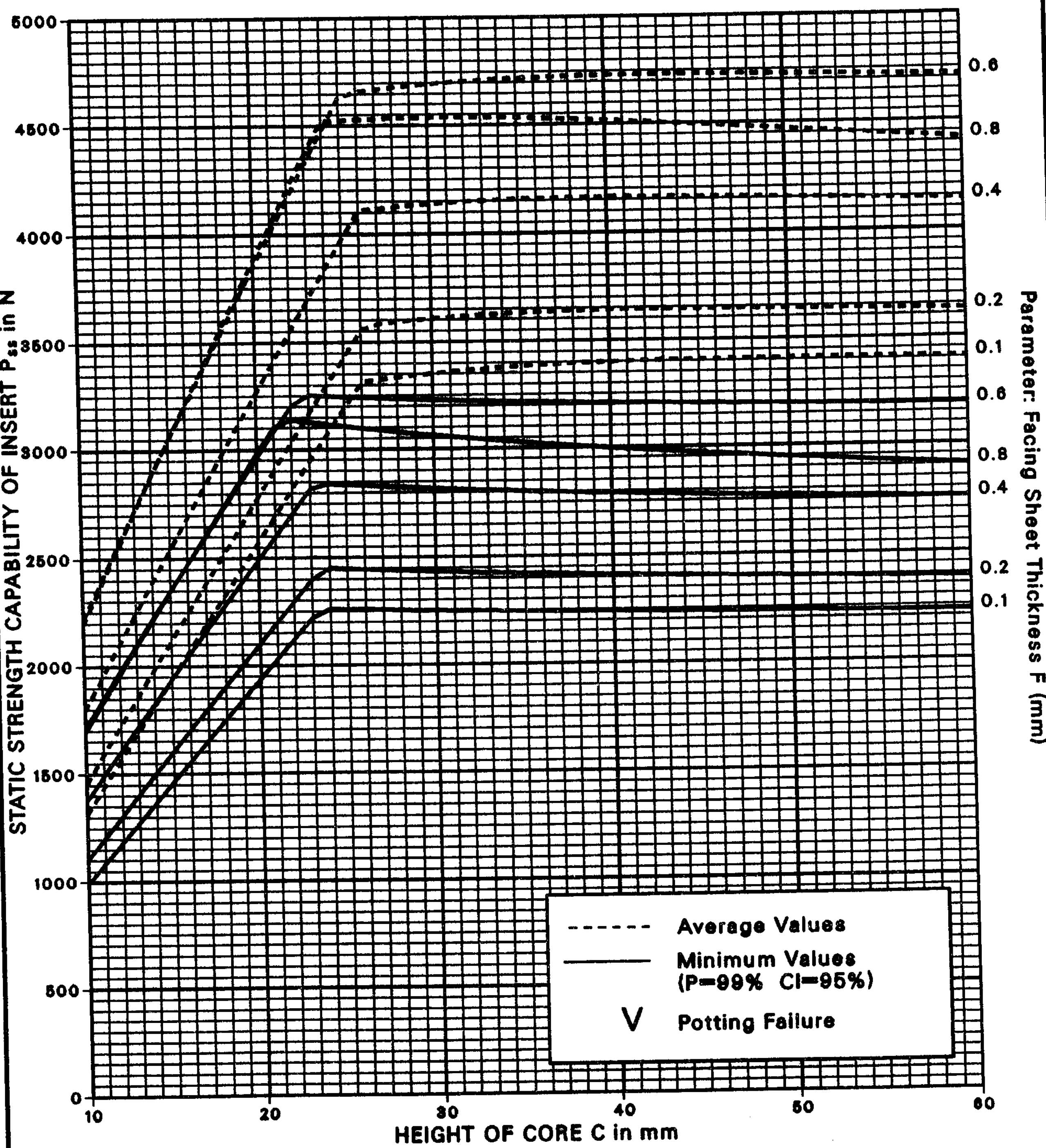


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 14.0 mm

Core : 1/8-5052-.001

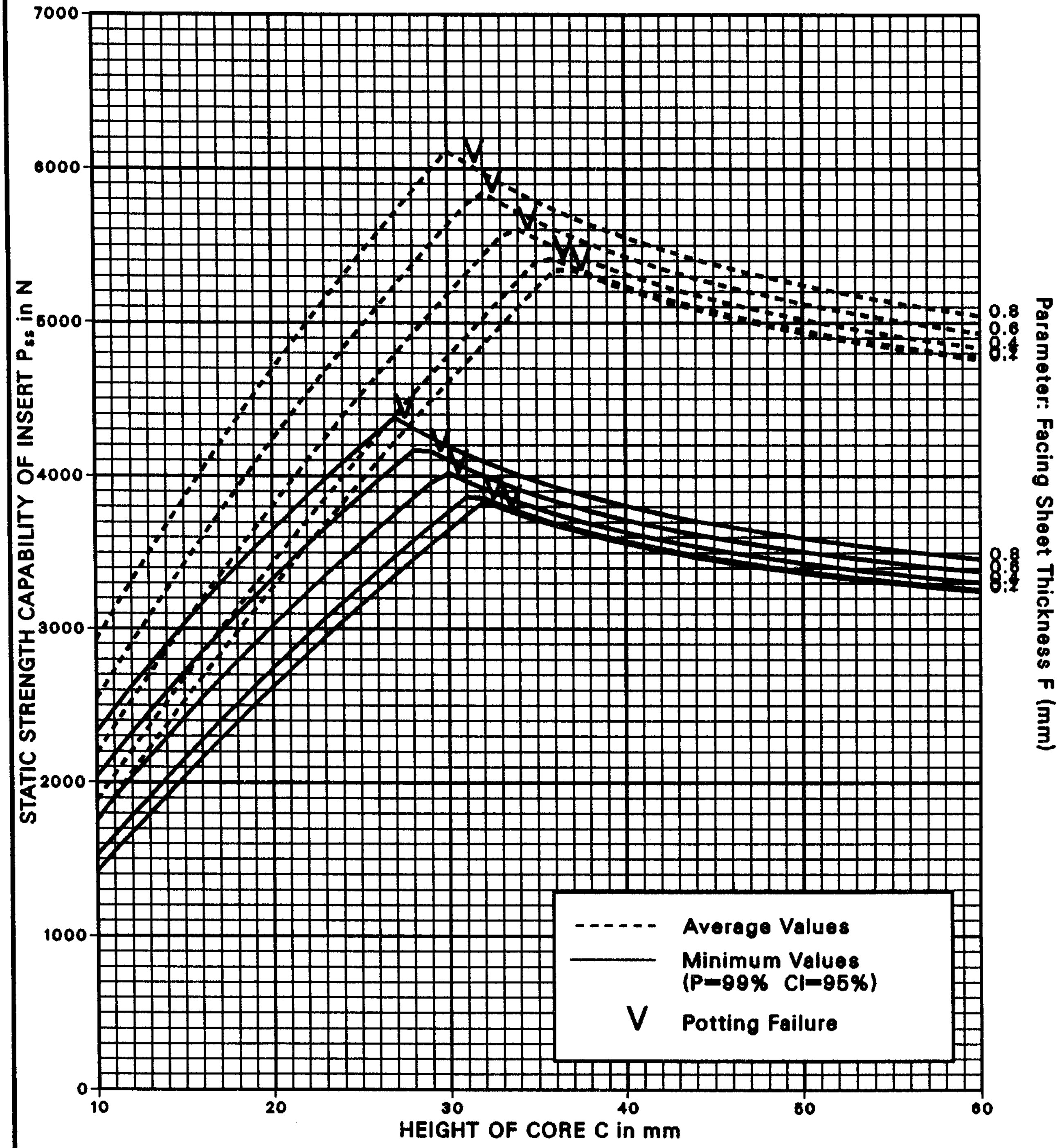


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **17.5 mm**

Core : **1/8-5052-.001**

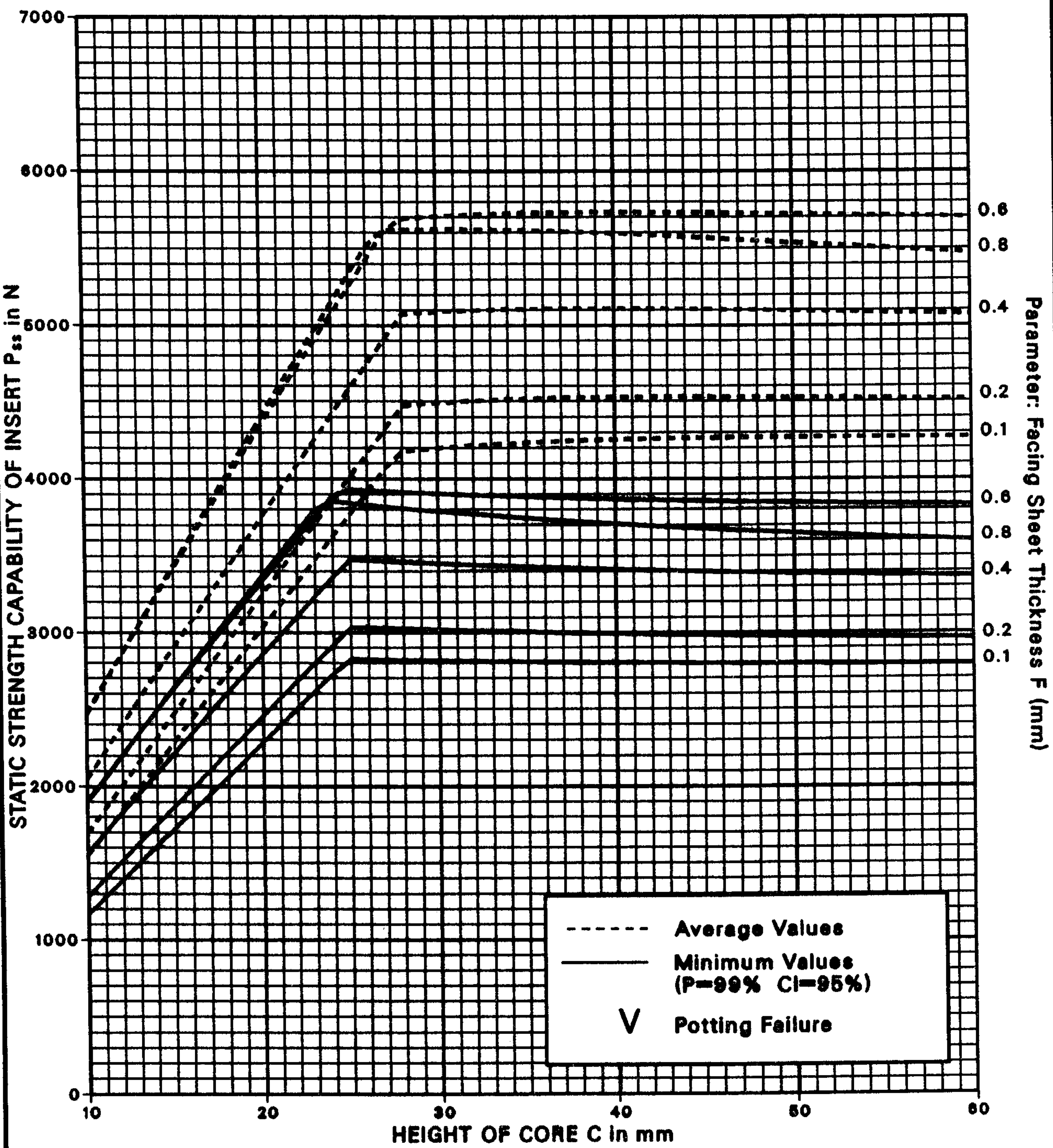


Insert Height h = 9 mm Facing Material AL 2024

Load : **Compression**

Insert Diameter: **17.5 mm**

Core : **1/8-5052-.001**

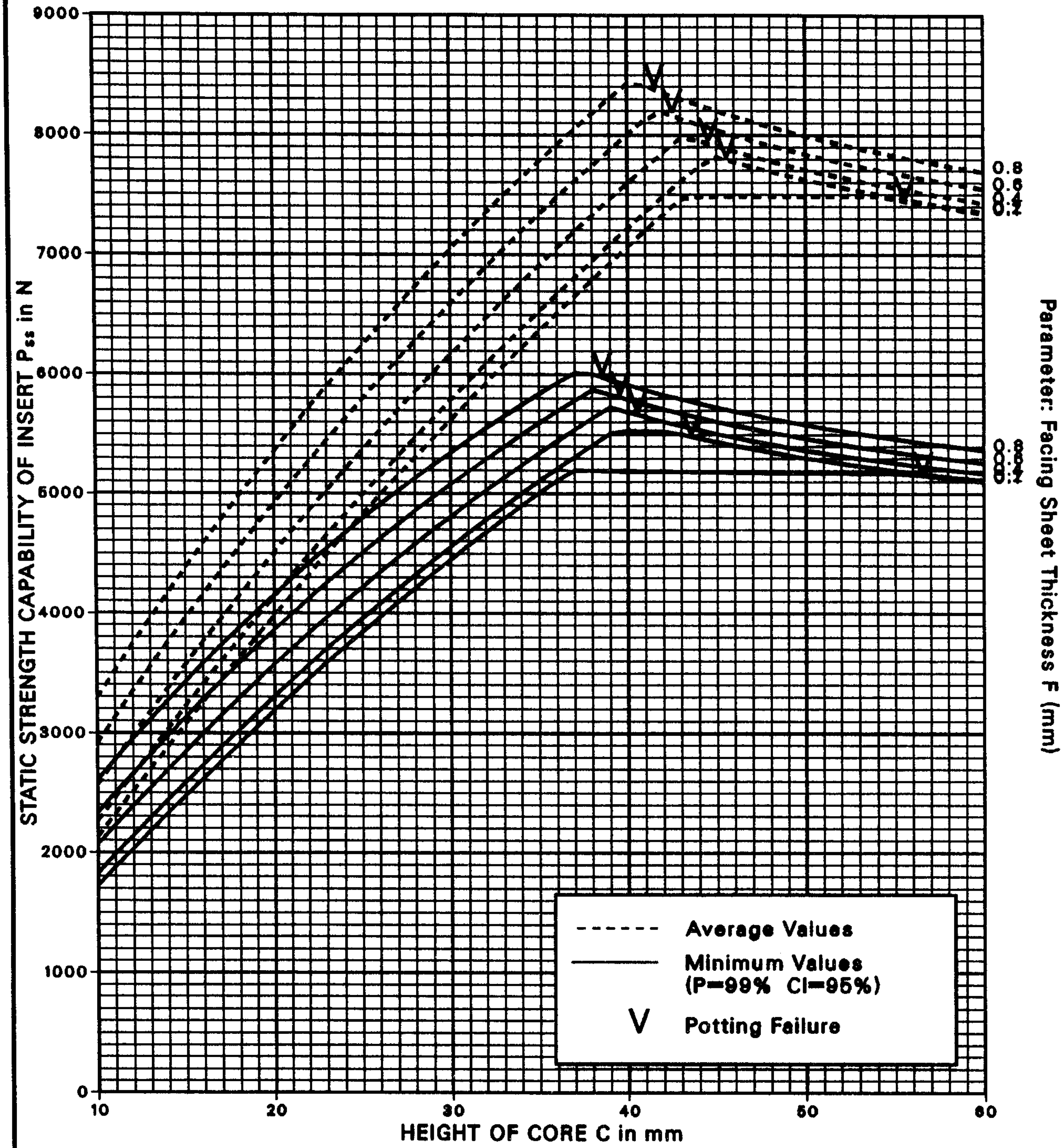


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **22.5 mm**

Core : **1/8-5052-.001**

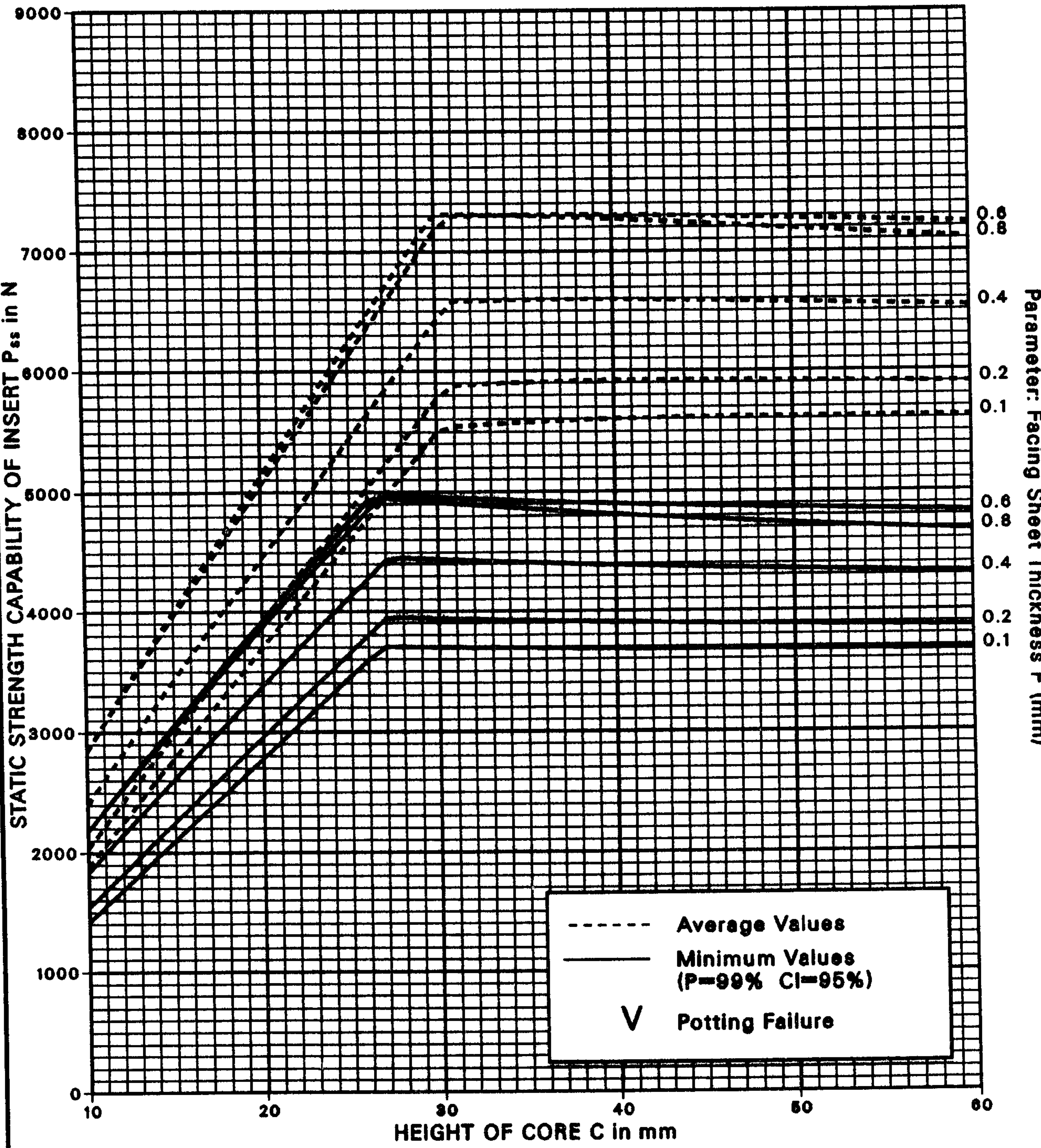


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 22.5 mm

Core : 1/8-5052-.001



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5. 3/16 – 5056 – 0.0007 Core

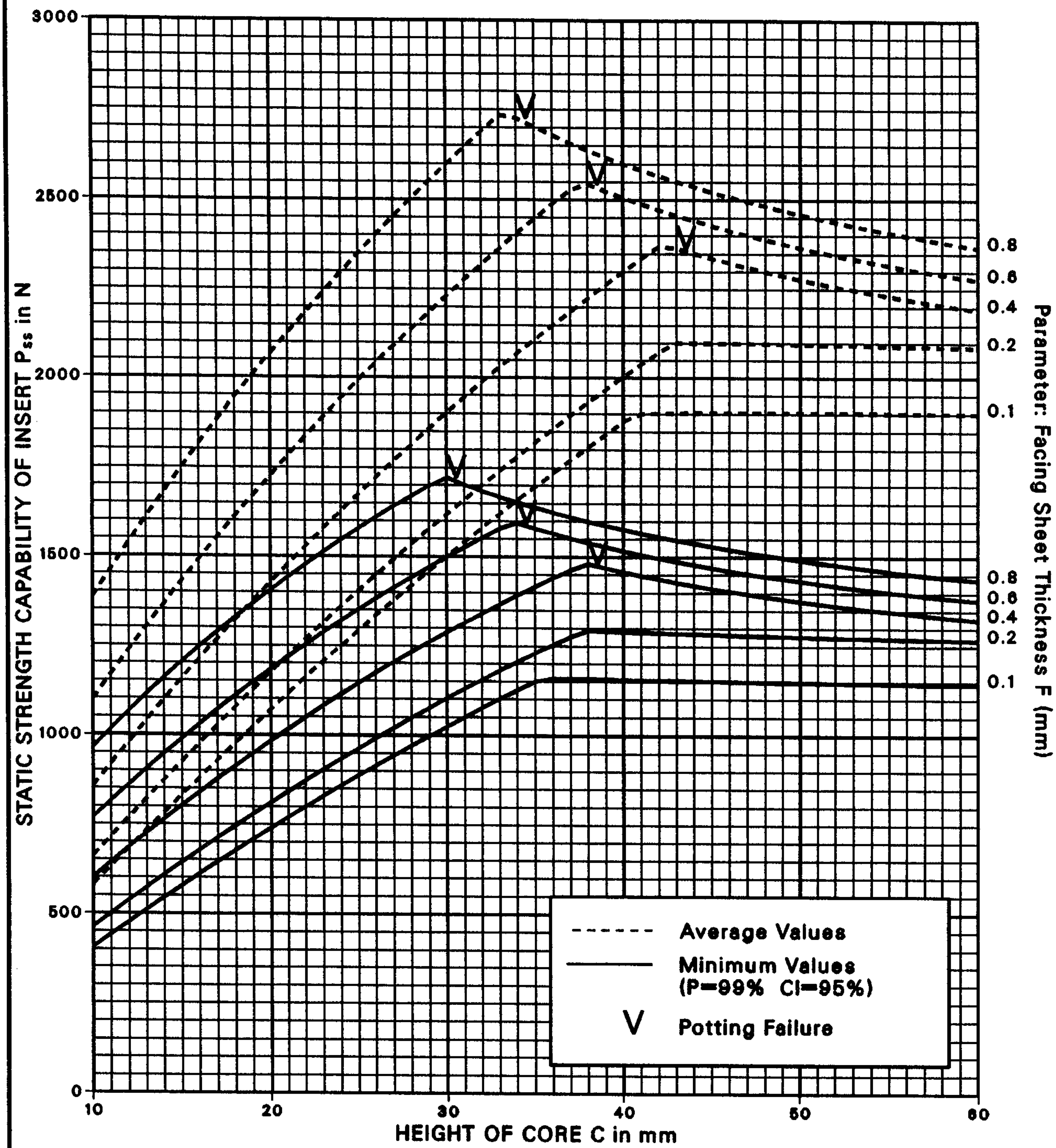
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **9.0 mm**

Core : **3/16-5056-.0007**

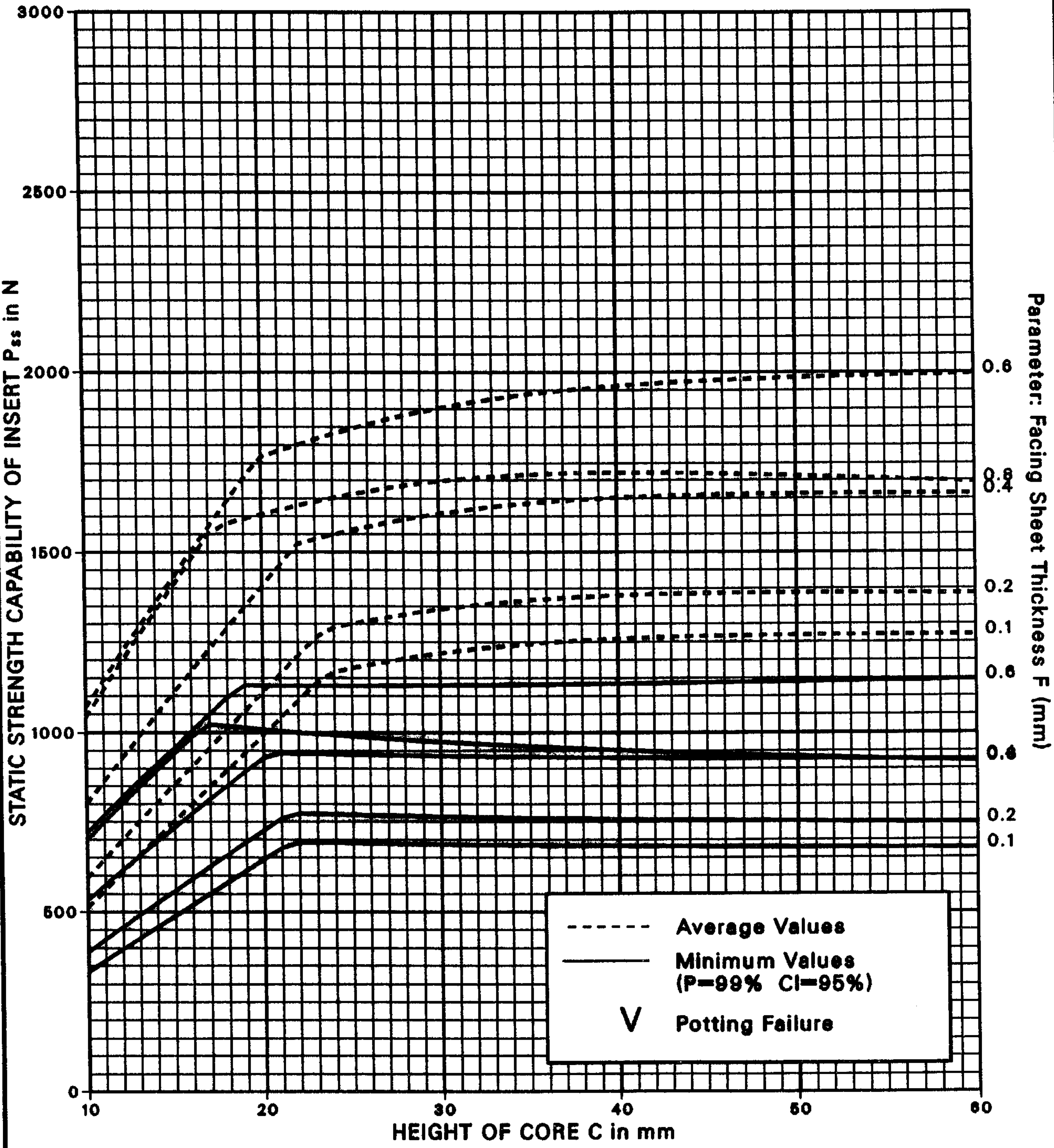


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 9.0 mm

Core : 3/16-5056-.0007



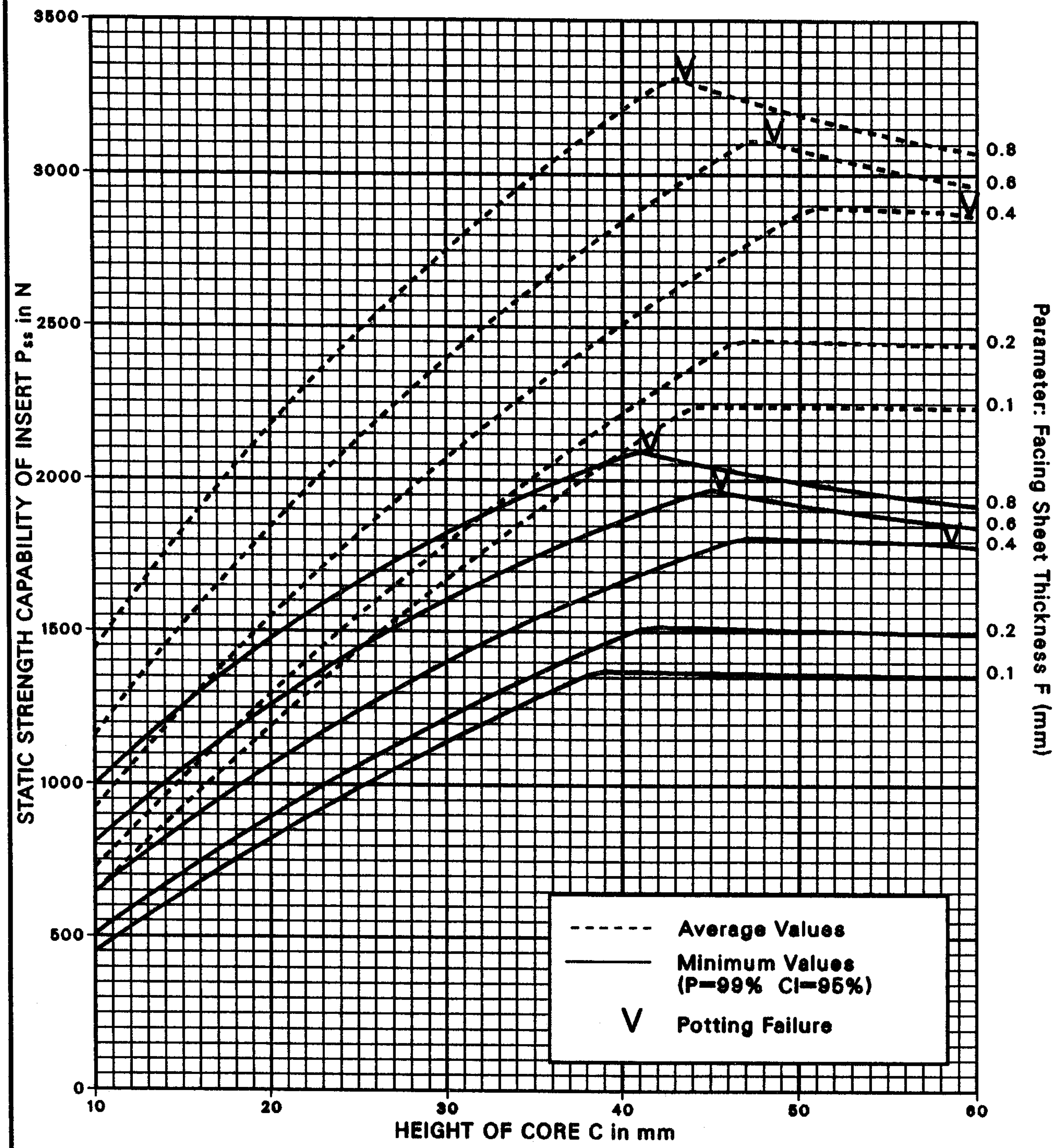
Version 2.0

Insert Height h = 9 mm	Facing Material AL 2024

Load : **Tension**

Insert Diameter: **11.0 mm**

Core : **3/16-5056-.0007**

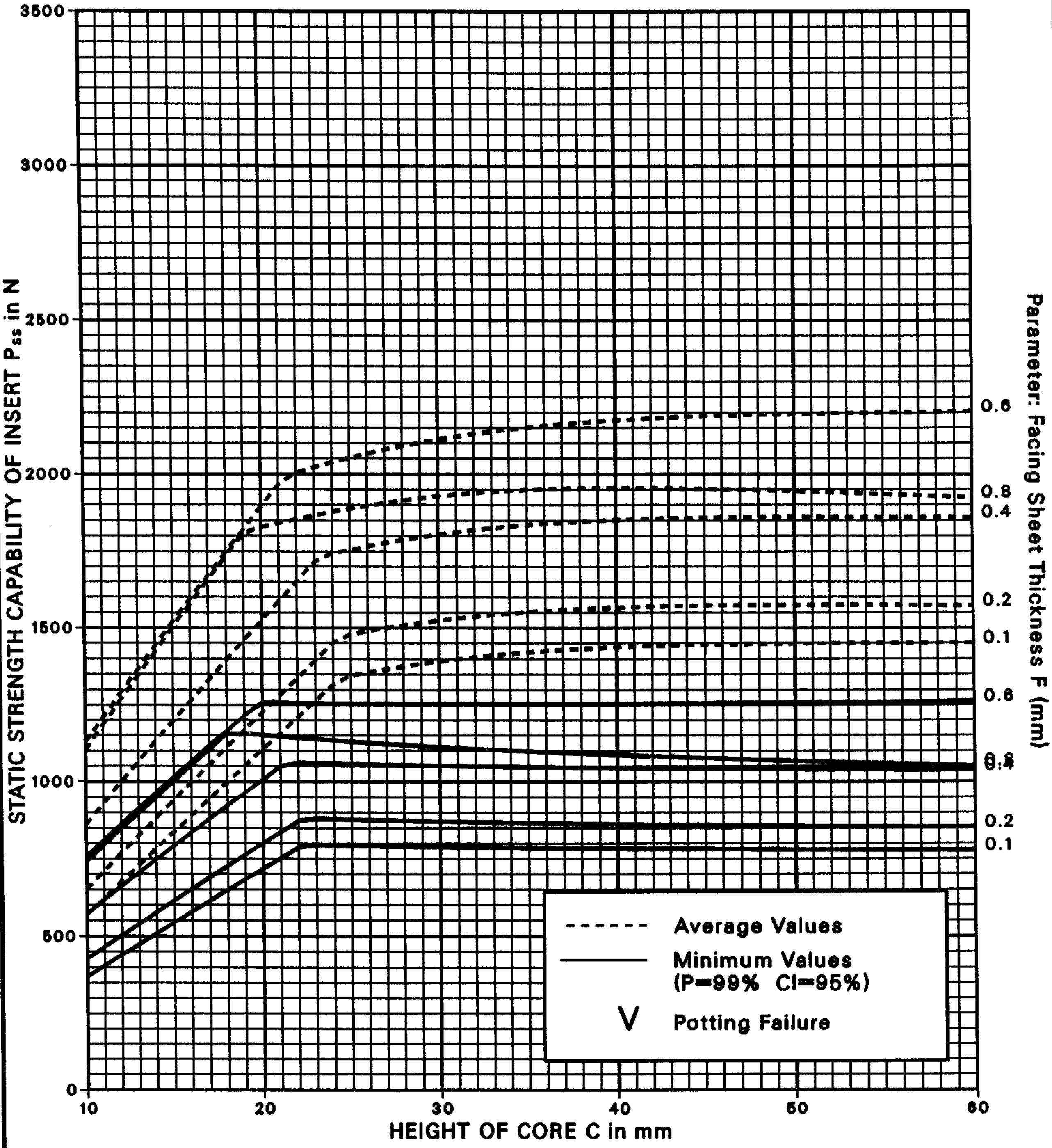


Insert Height h = 9 mm Facing Material AL 2024

Load : Compression

Insert Diameter: 11.0 mm

Core : 3/16-5056-.0007

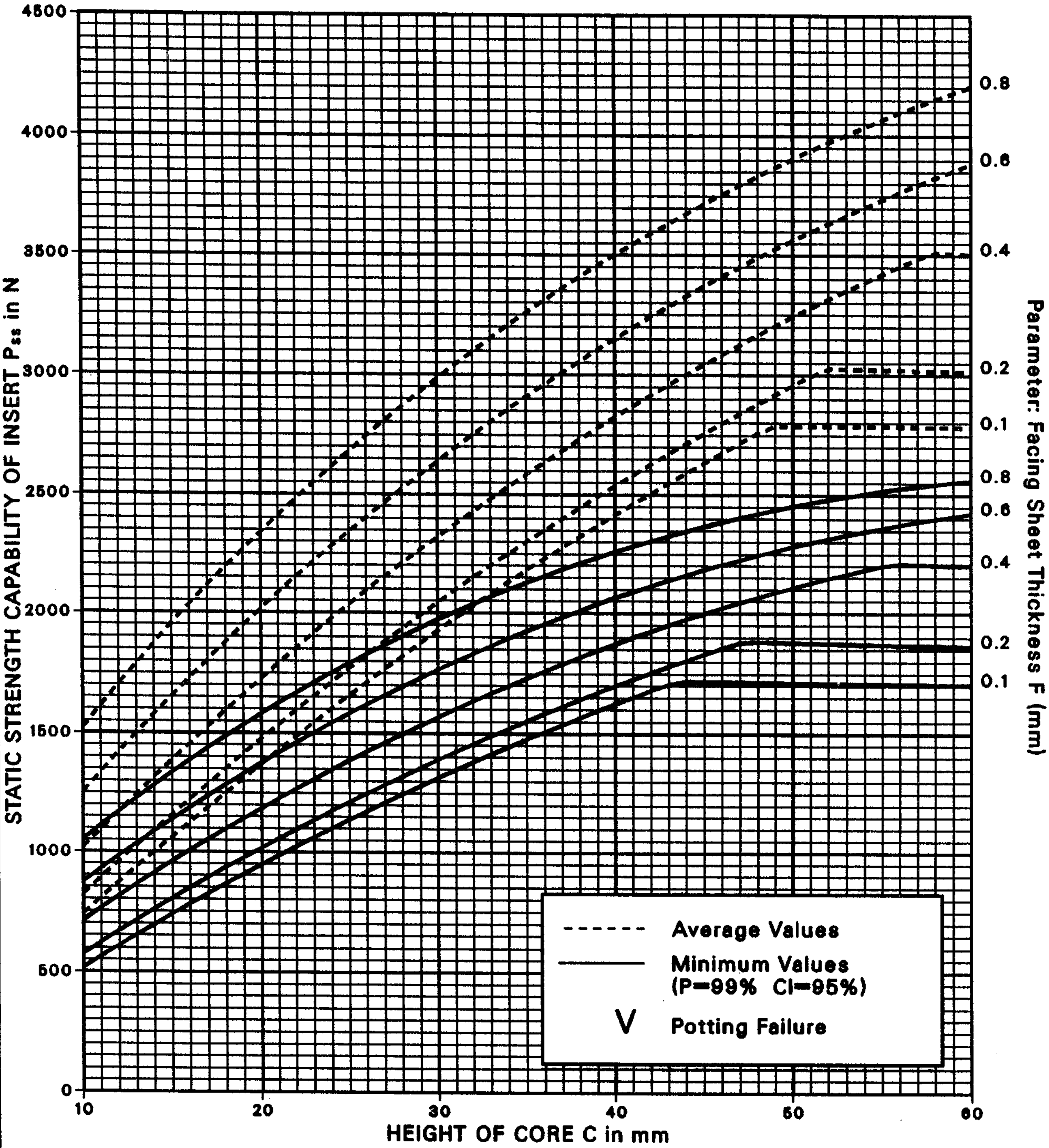


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **14.0 mm**

Core : **3/16-5056-.0007**

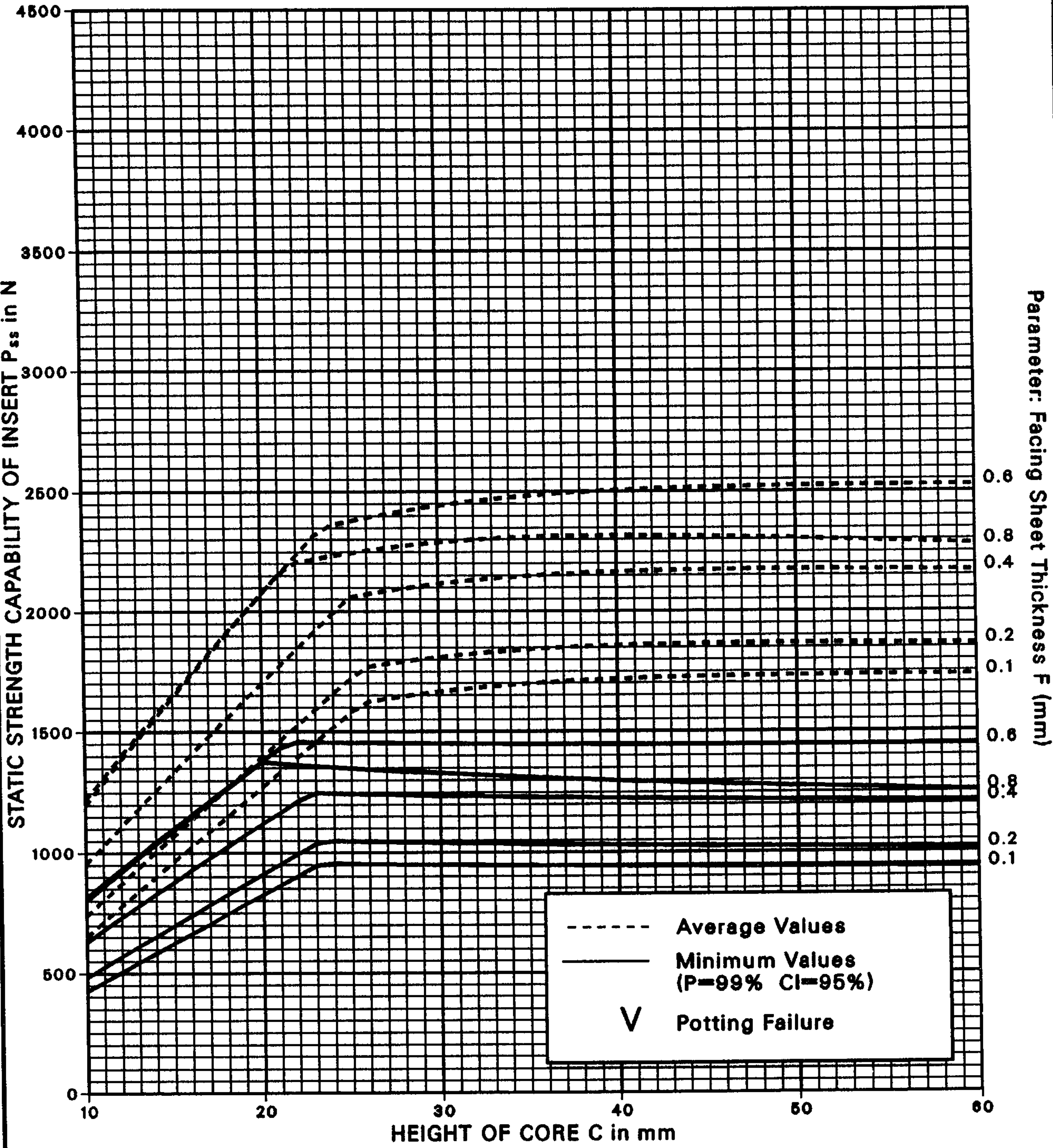


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 14.0 mm

Core : 3/16-5056-.0007

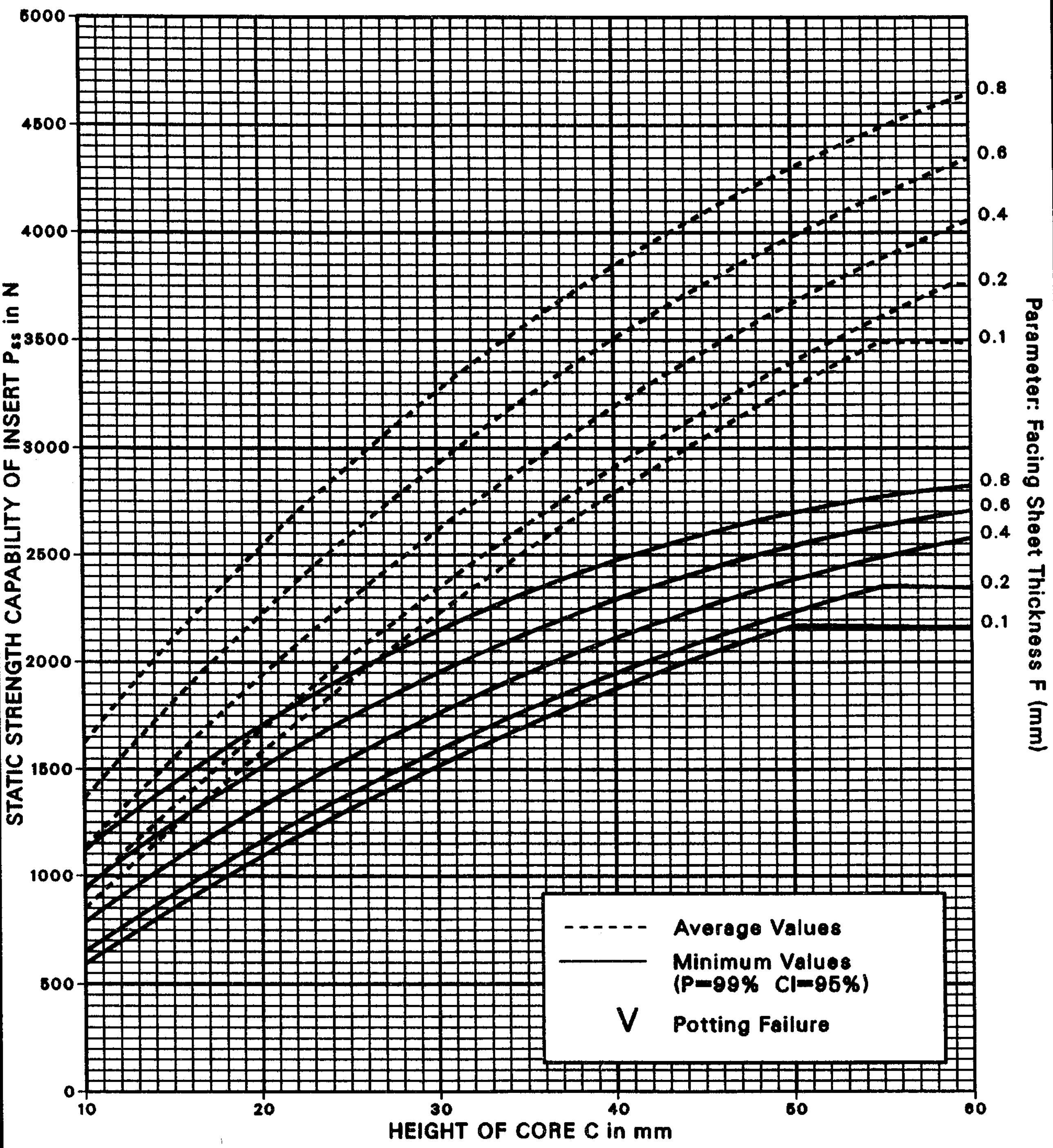


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **17.5 mm**

Core : **3/16-5056-.0007**

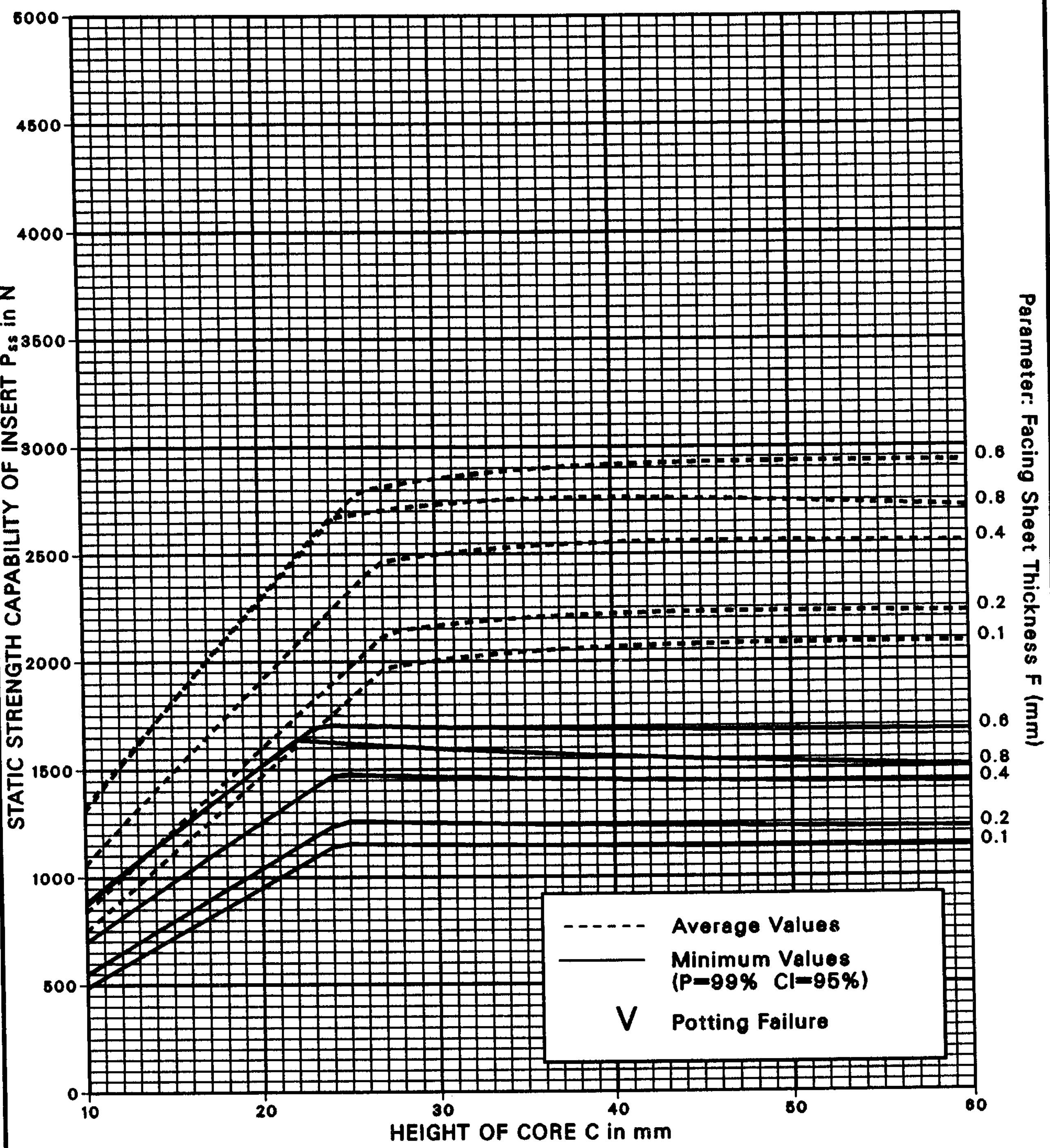


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 17.5 mm

Core : 3/16-5056-.0007

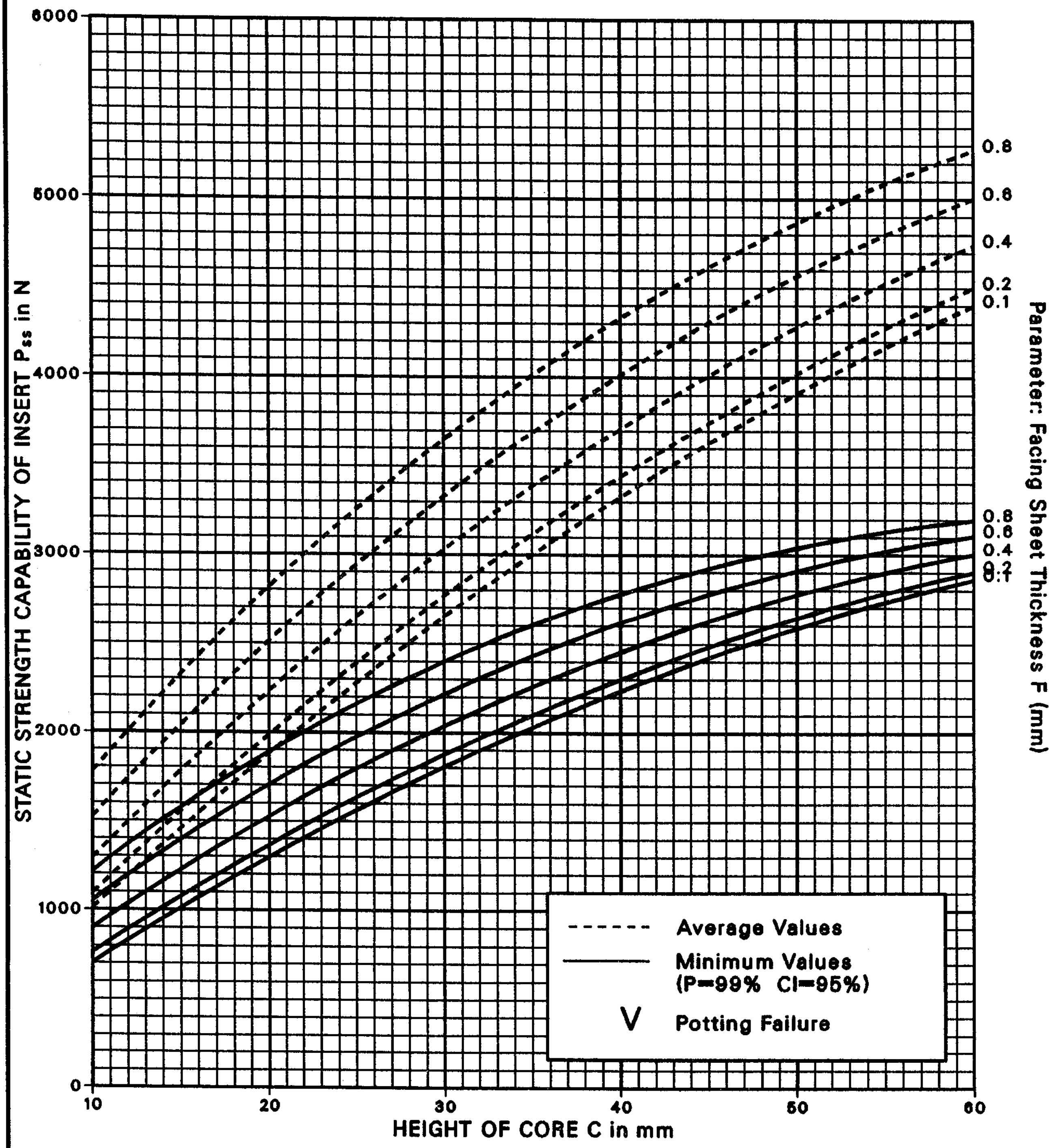


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **22.5 mm**

Core : **3/16-5056-.0007**



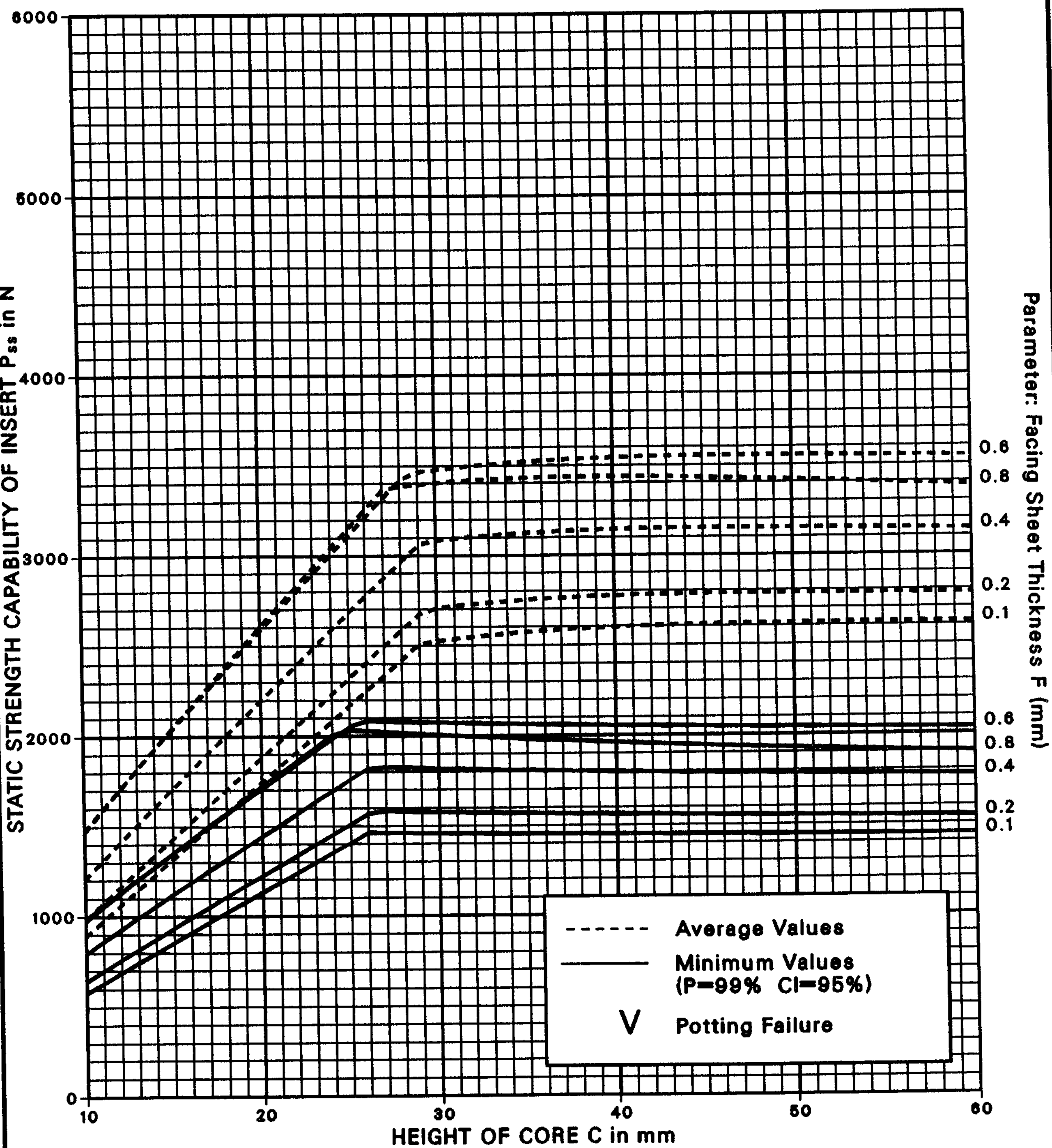
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Compression**

Insert Diameter: **22.5 mm**

Core : **3/16-5056-.0007**



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6. 3/16 – 5056 – 0.001 Core

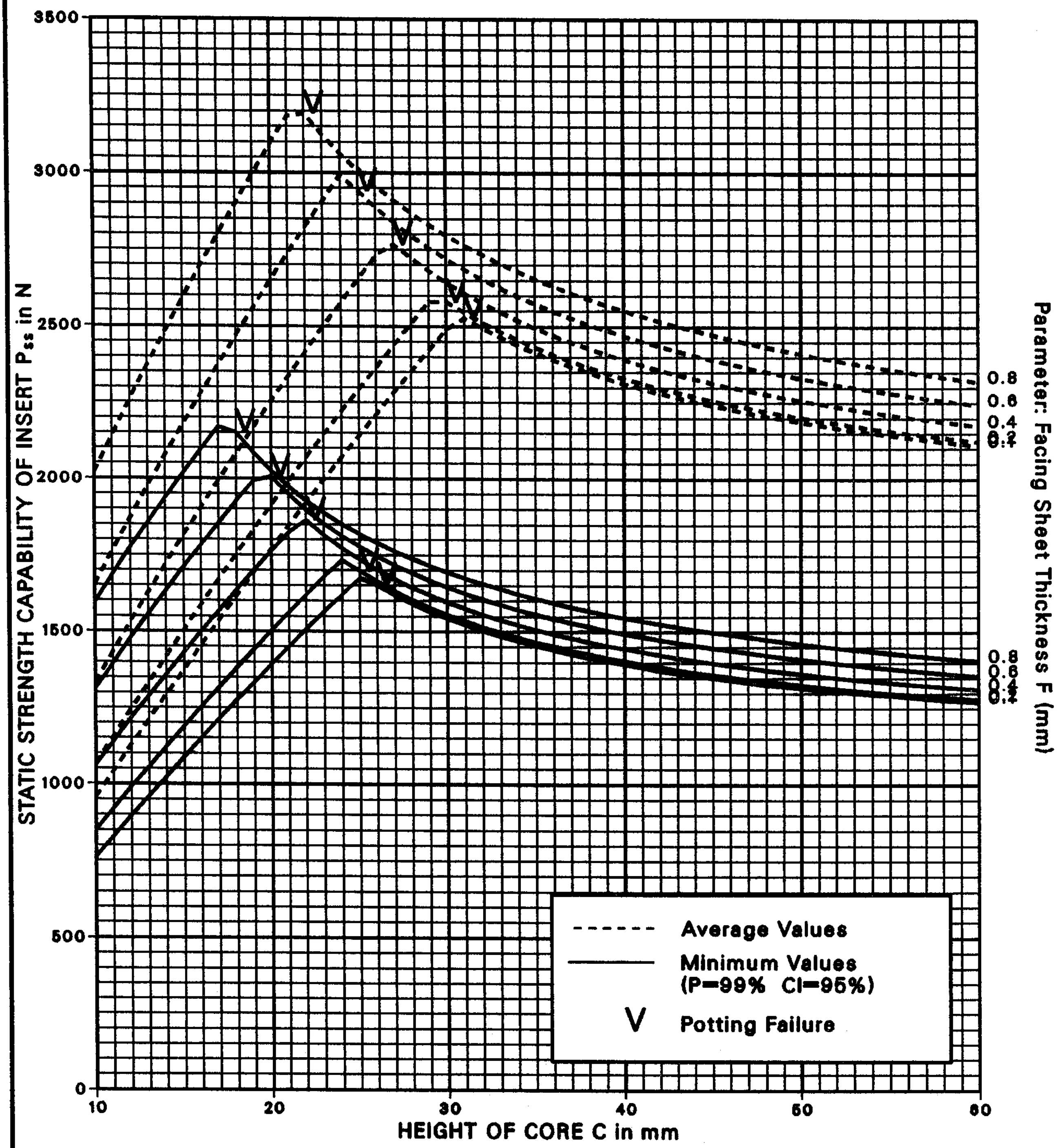
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **9.0 mm**

Core : **3/16-5056-.001**

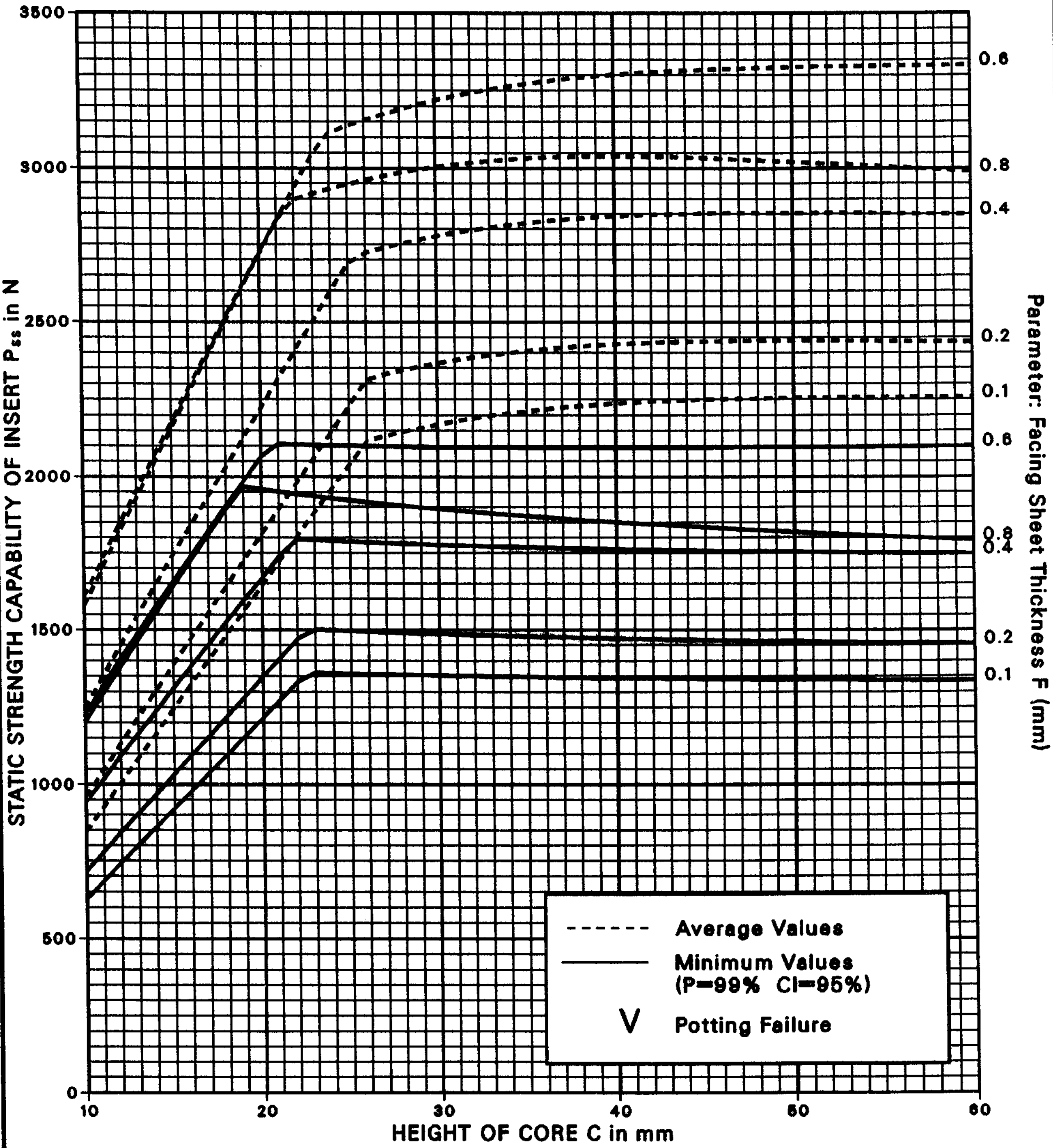


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Compression**

Insert Diameter: **9.0 mm**

Core : **3/16-5056-.001**



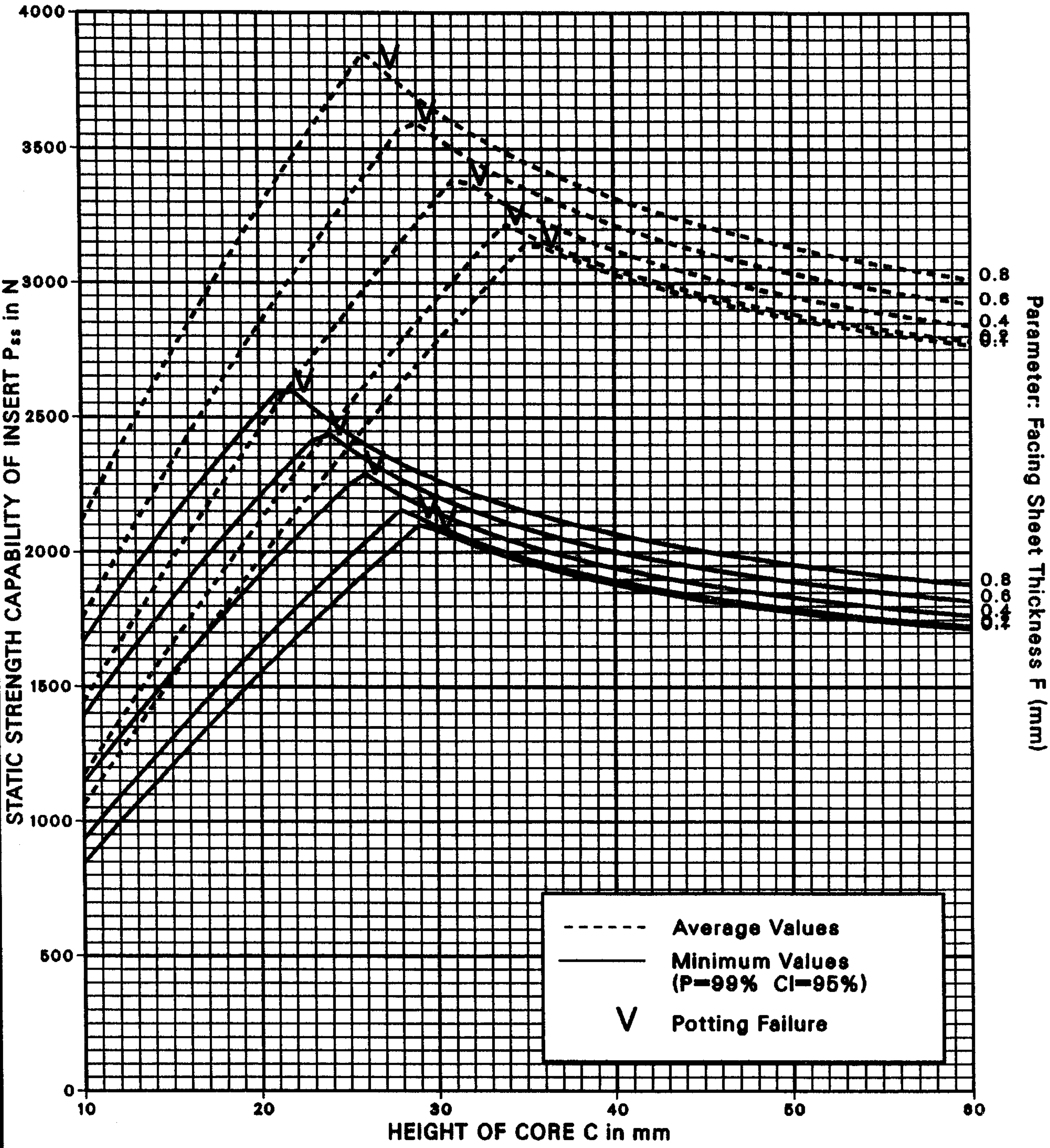
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **11.0 mm**

Core : **3/16-5056-.001**

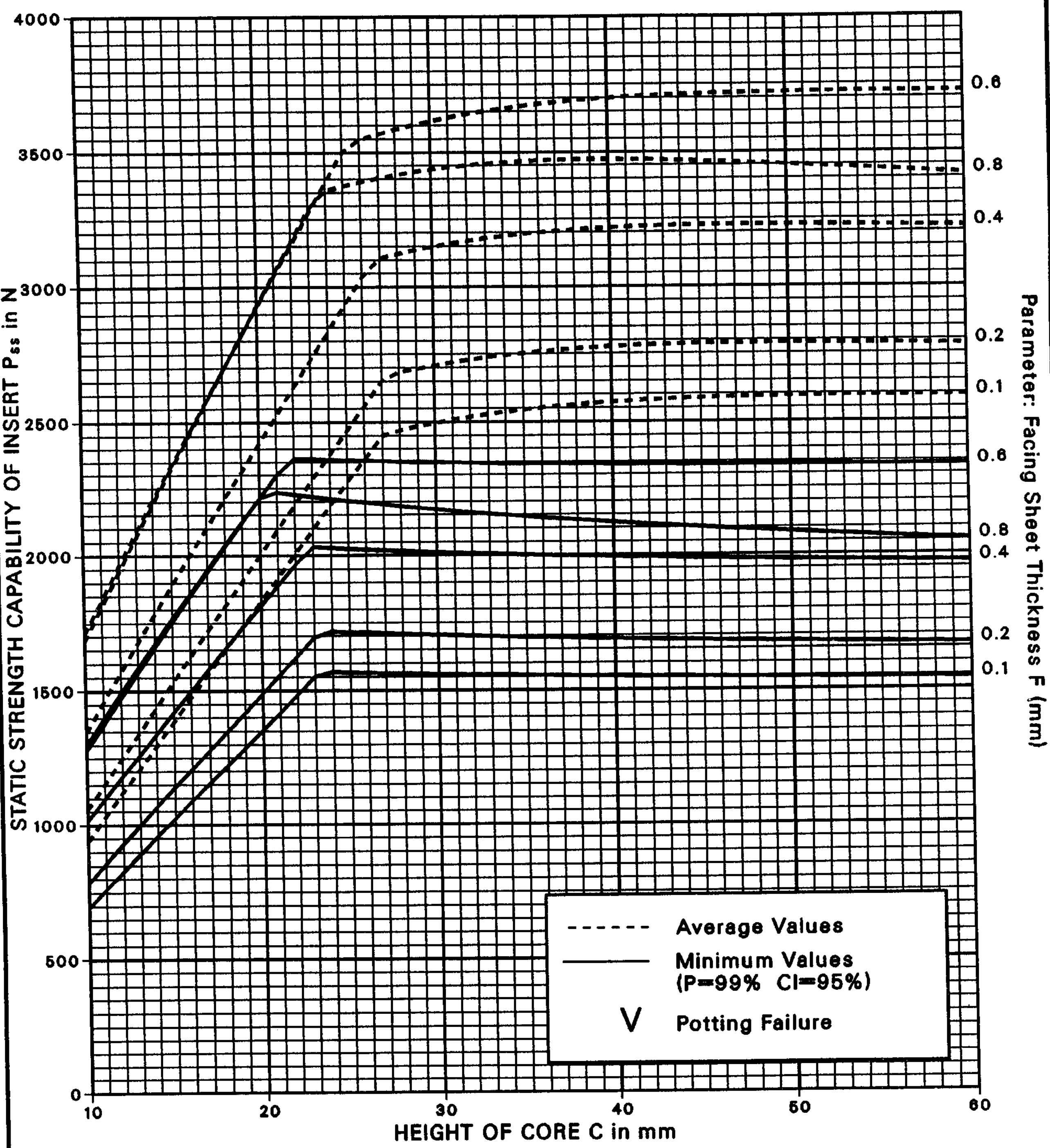


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 11.0 mm

Core : 3/16-5056-.001

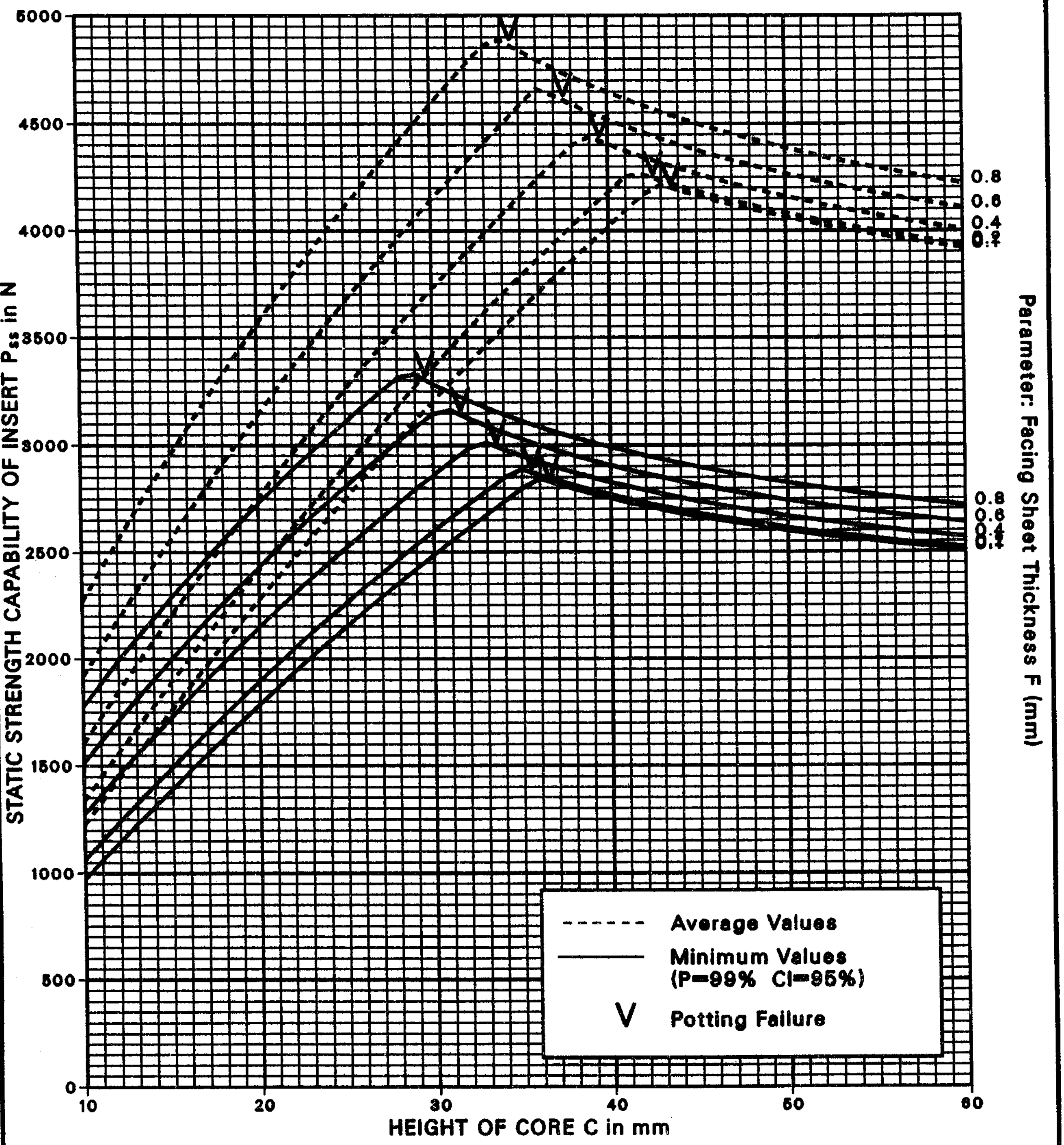


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **14.0 mm**

Core : **3/16-5056-.001**

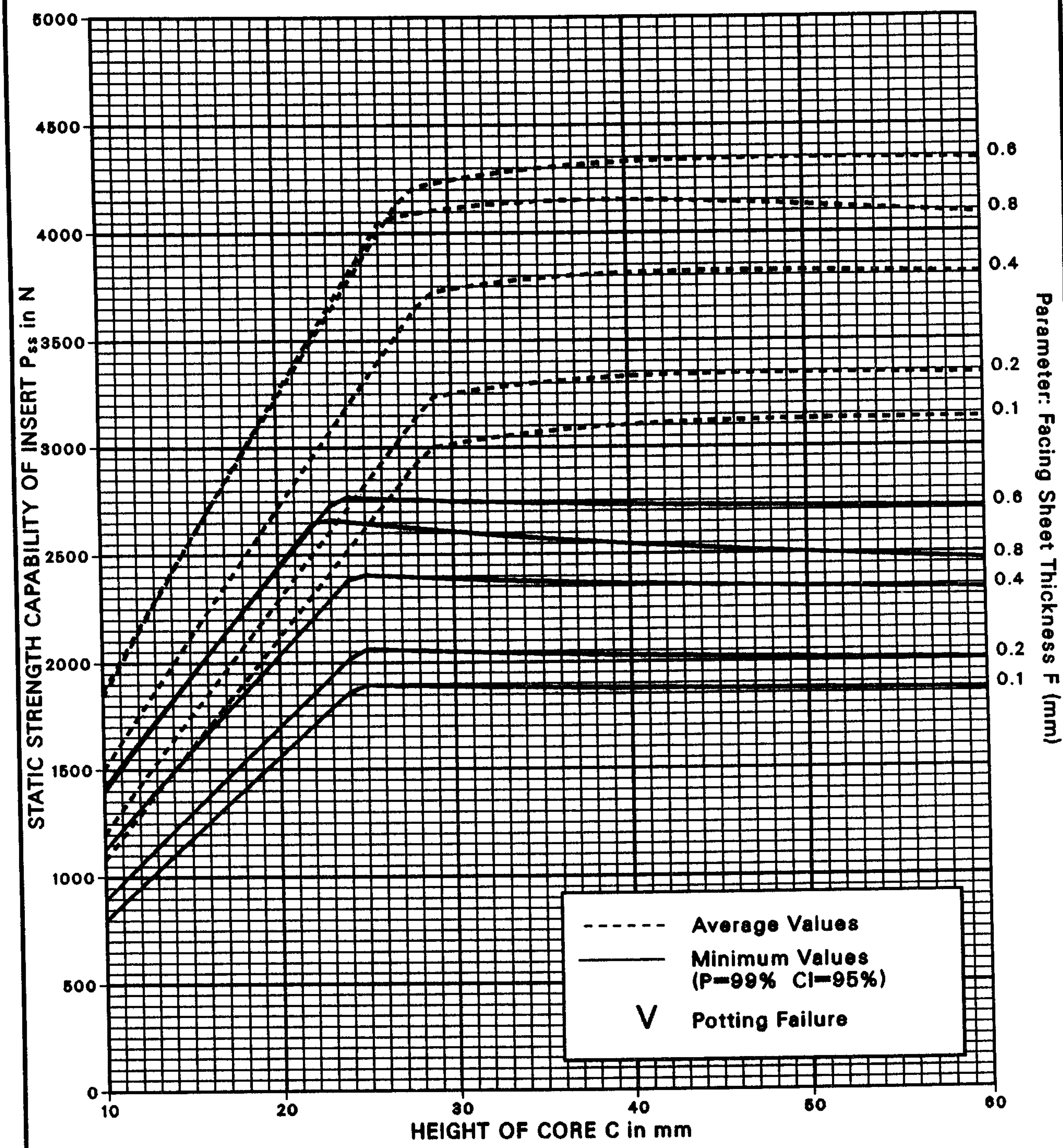


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 14.0 mm

Core : 3/16-5056-.001

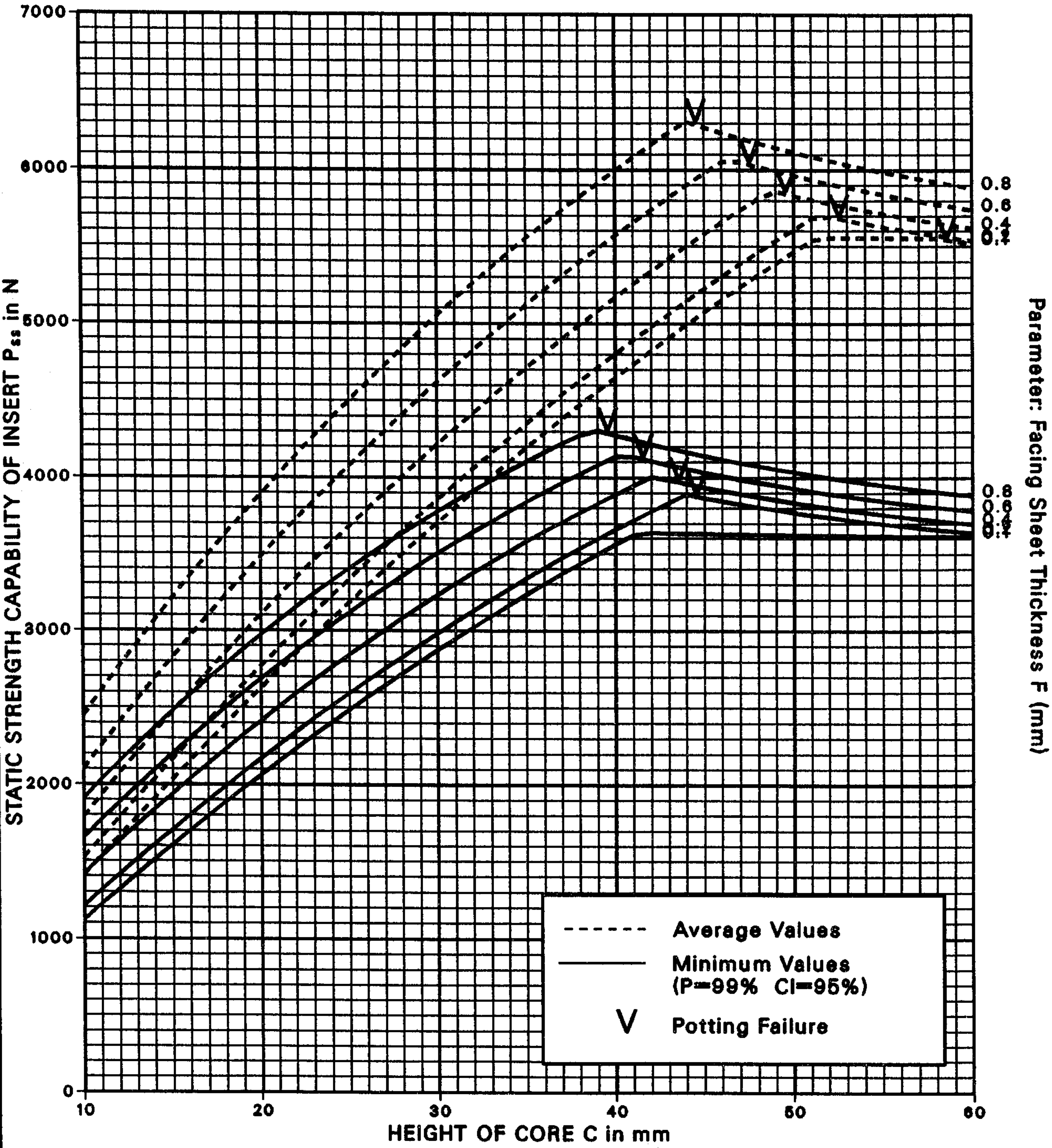


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **17.5 mm**

Core : **3/16-5056-.001**

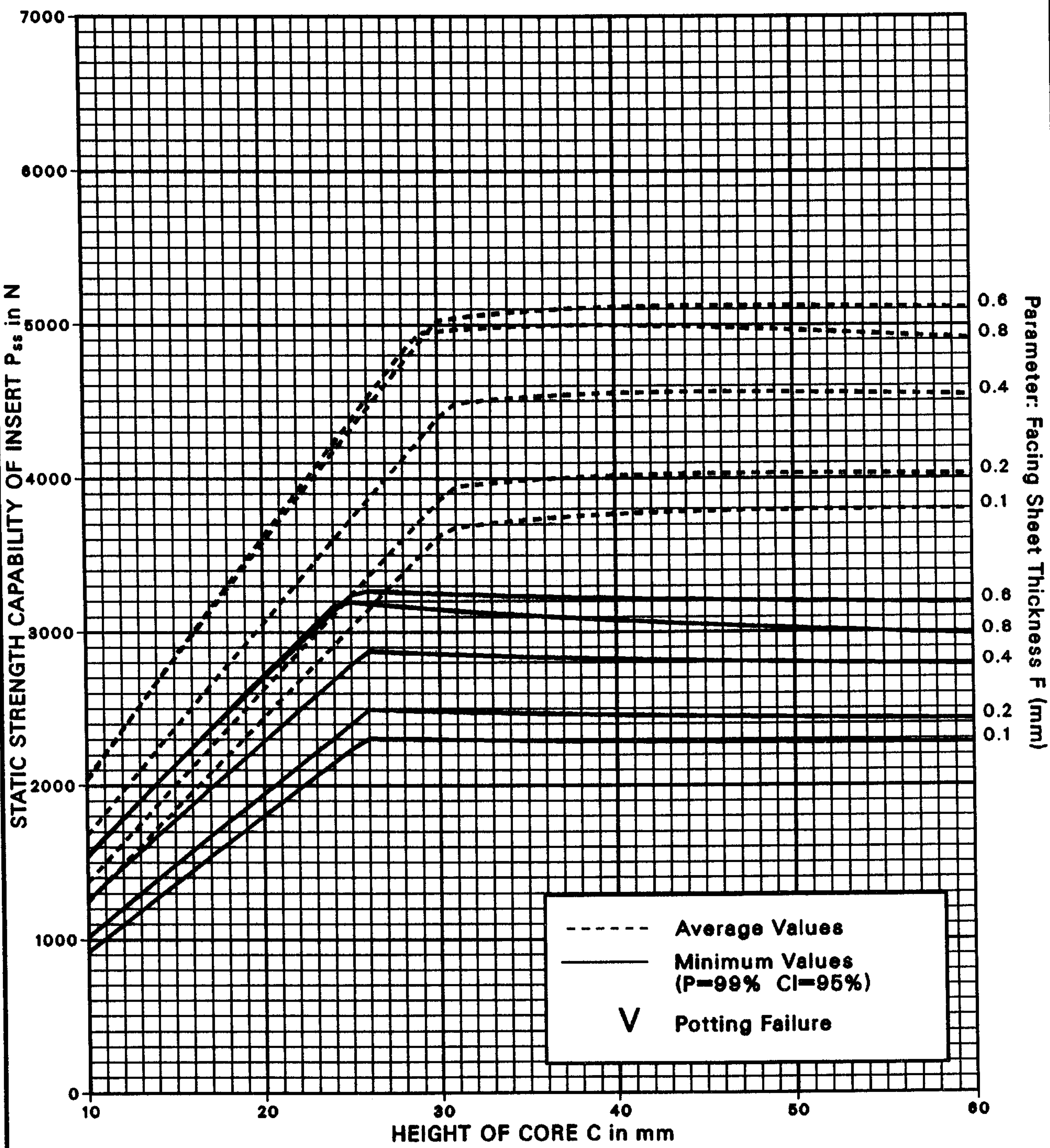


Insert Height h = 9 mm Facing Material AL 2024

Load : Compression

Insert Diameter: 17.5 mm

Core : 3/16-5056-.001



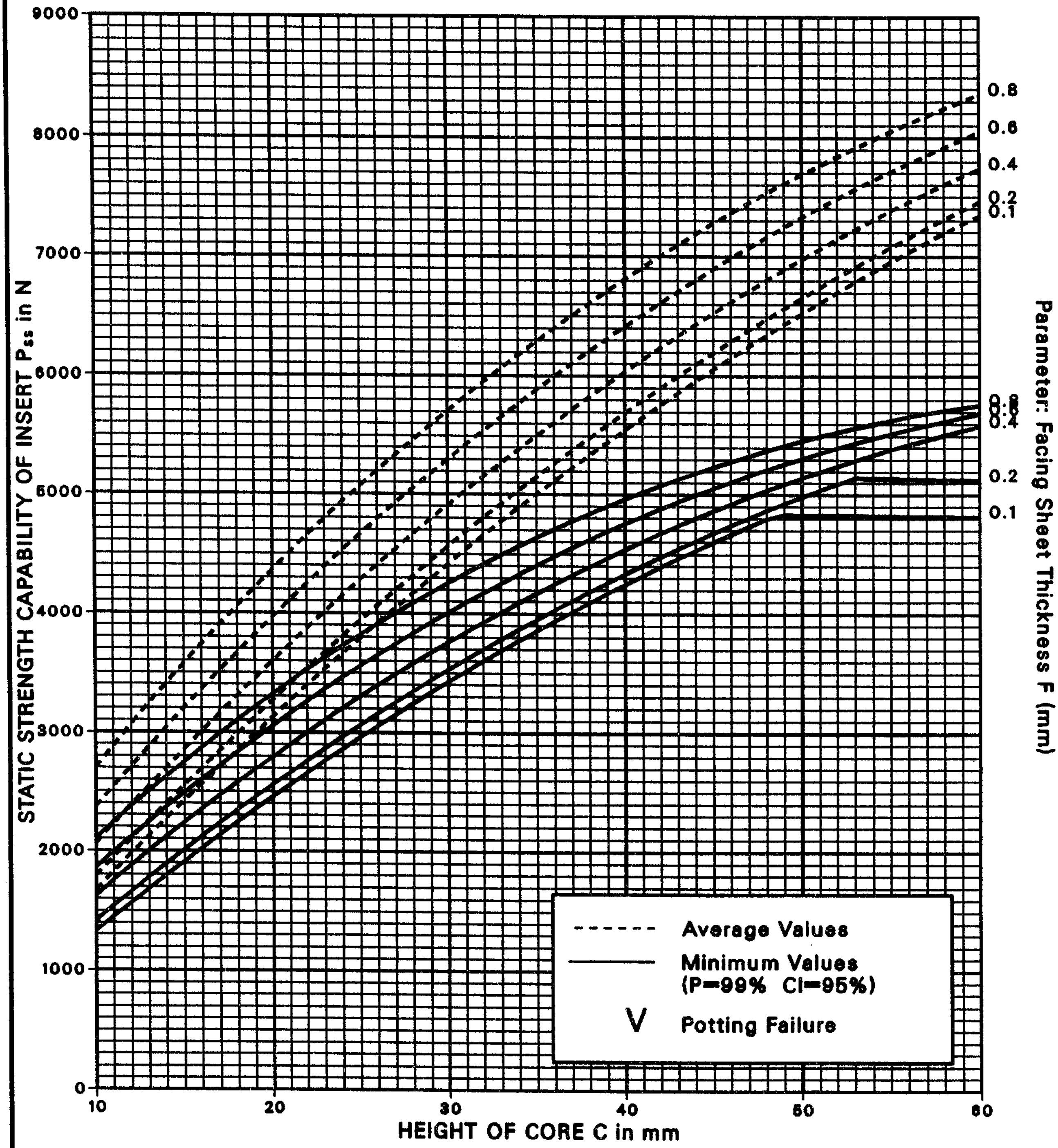
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **22.5 mm**

Core : **3/16-5056-.001**

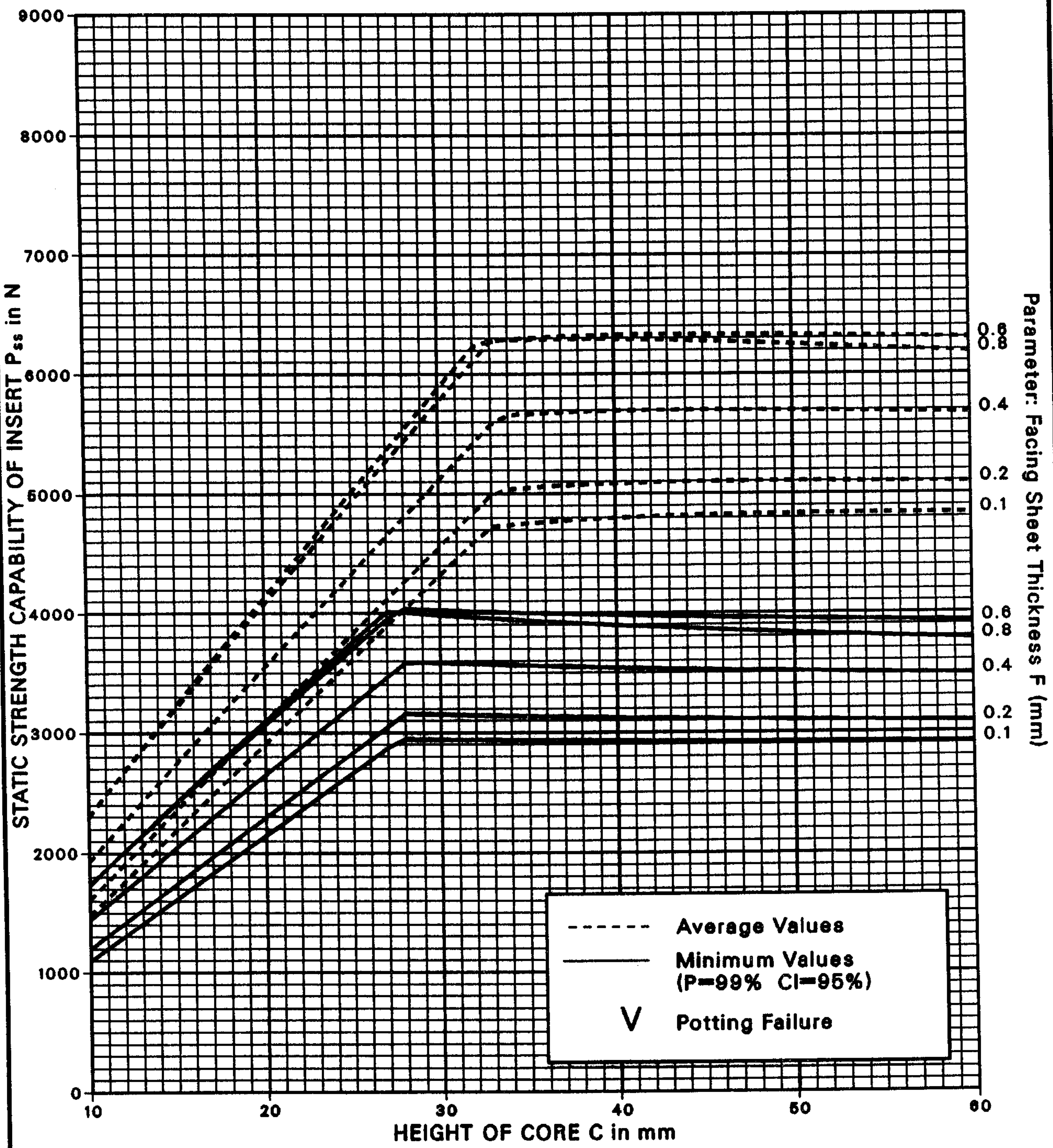


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 22.5 mm

Core : 3/16-5056-.001



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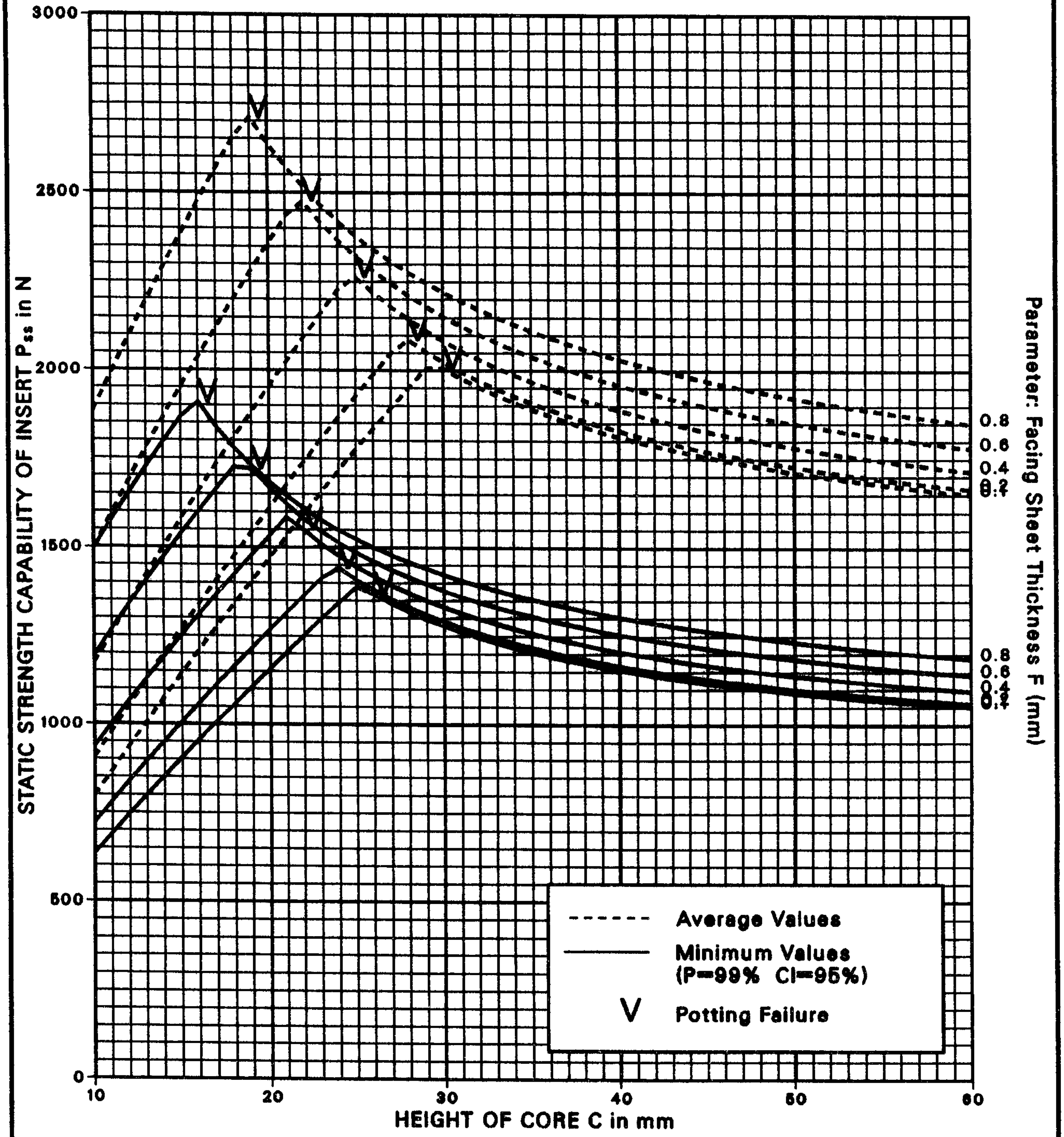
7. 1/8 – 5056 – 0.0007 Core

Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **9.0 mm**

Core : **1/8-5056-.0007**

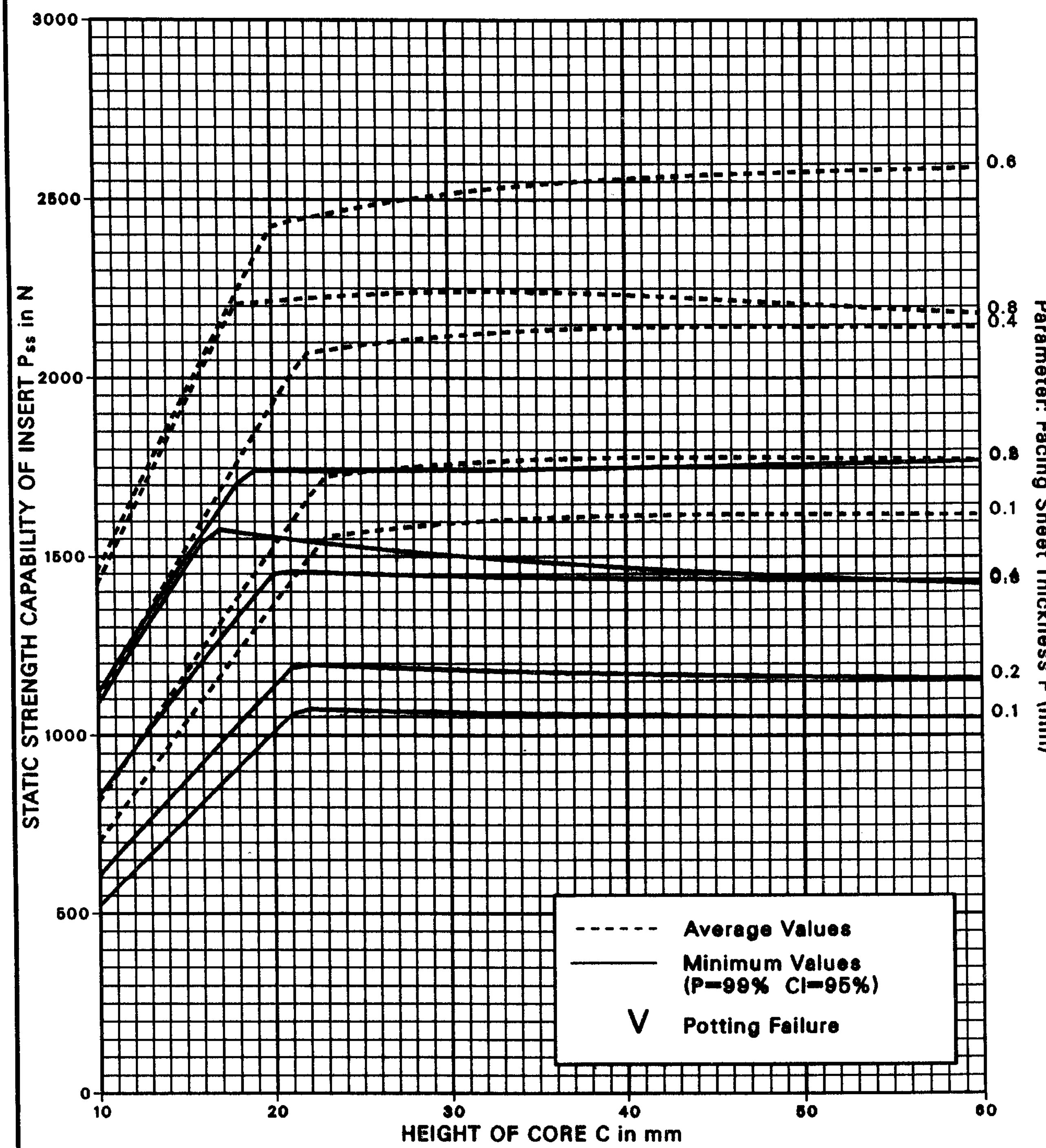


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Compression**

Insert Diameter: **9.0 mm**

Core : **1/8-5056-.0007**



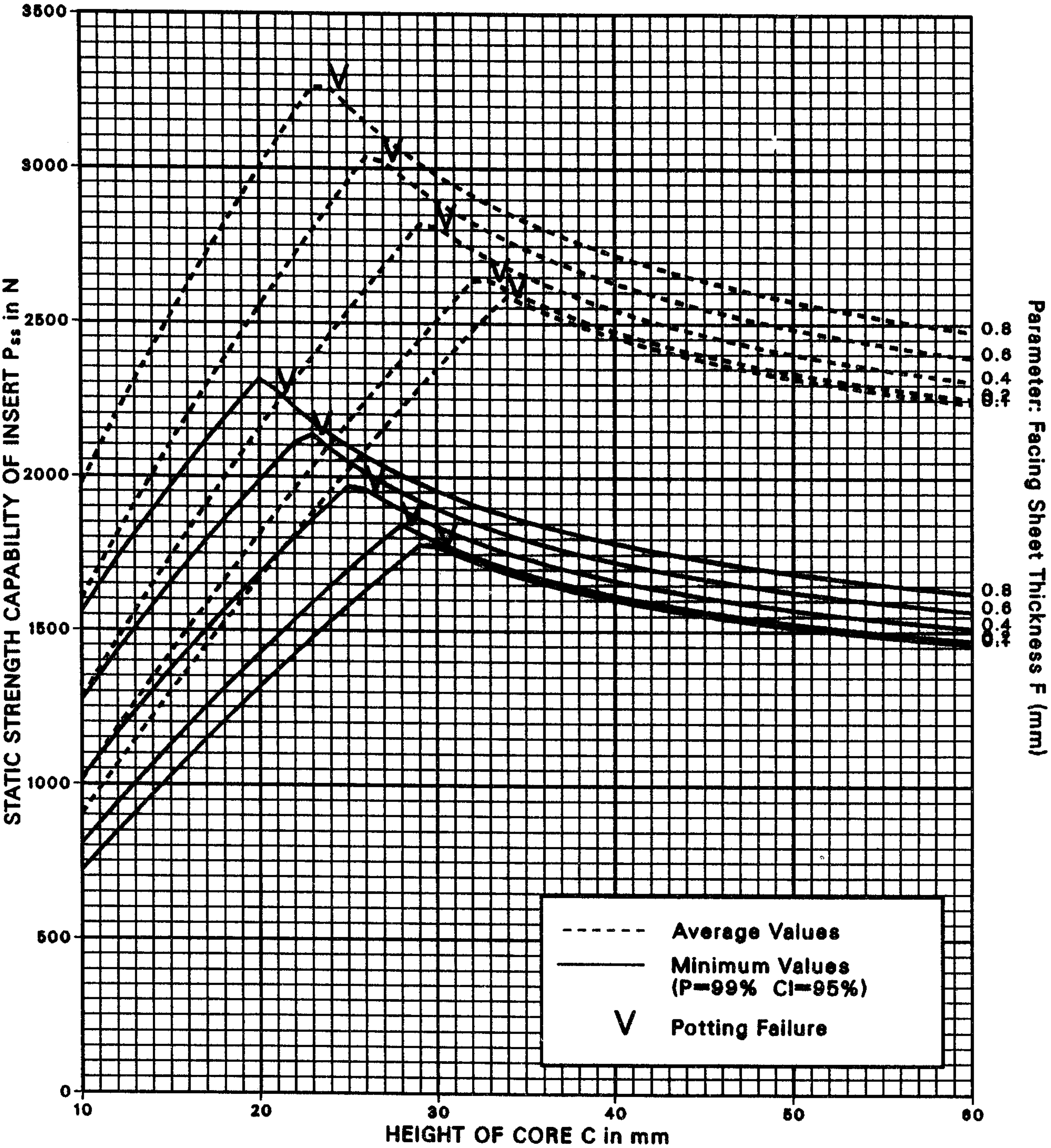
Insert Height h = 9 mm

Facing Material AL 2024

Load : Tension

Insert Diameter: 11.0 mm

Core : 1/8-5056-.0007

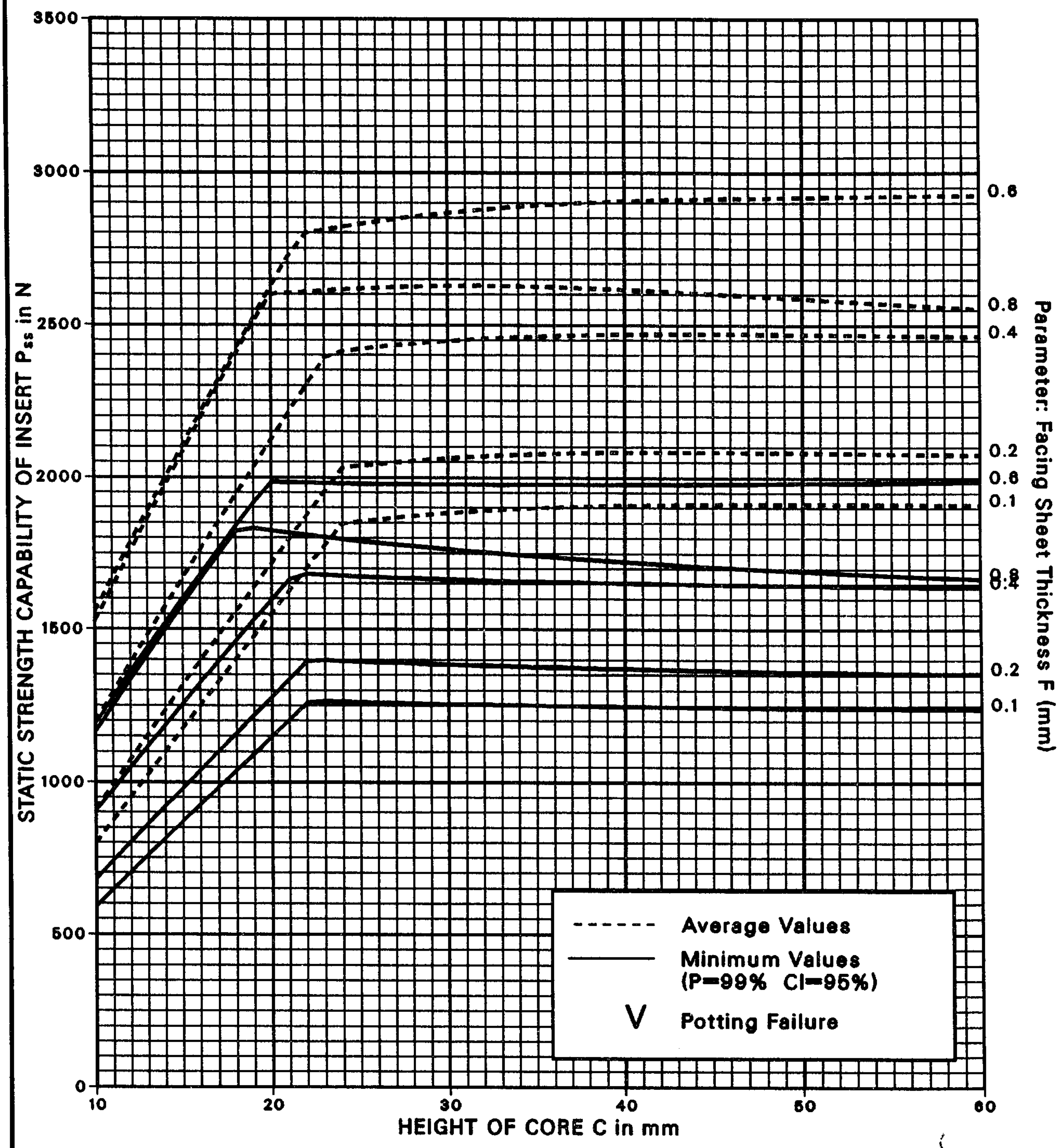


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 11.0 mm

Core : 1/8-5056-.0007



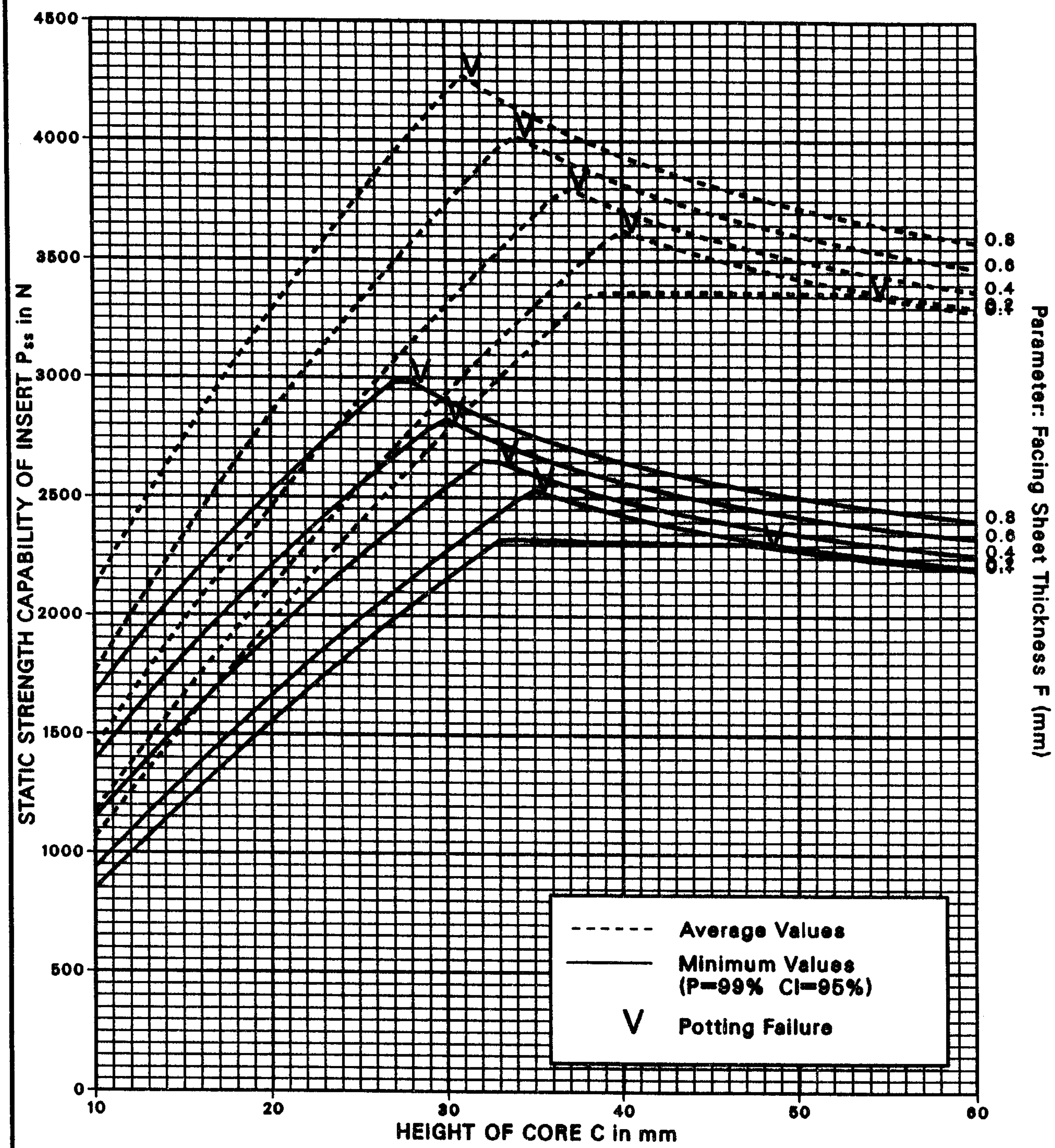
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **14.0 mm**

Core : **1/8-5056-.0007**

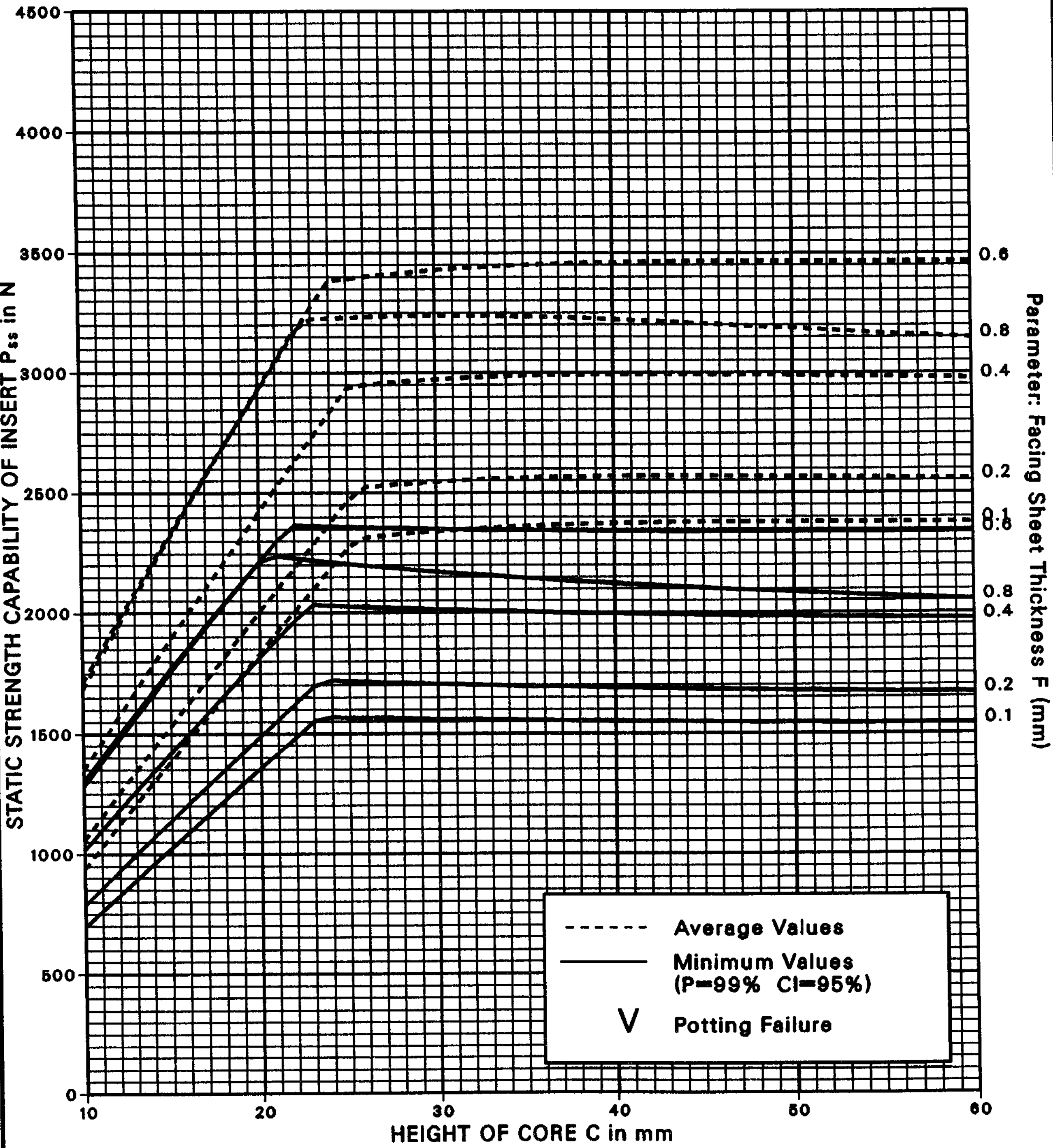


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Compression**

Insert Diameter: **14.0 mm**

Core : **1/8-5056-.0007**

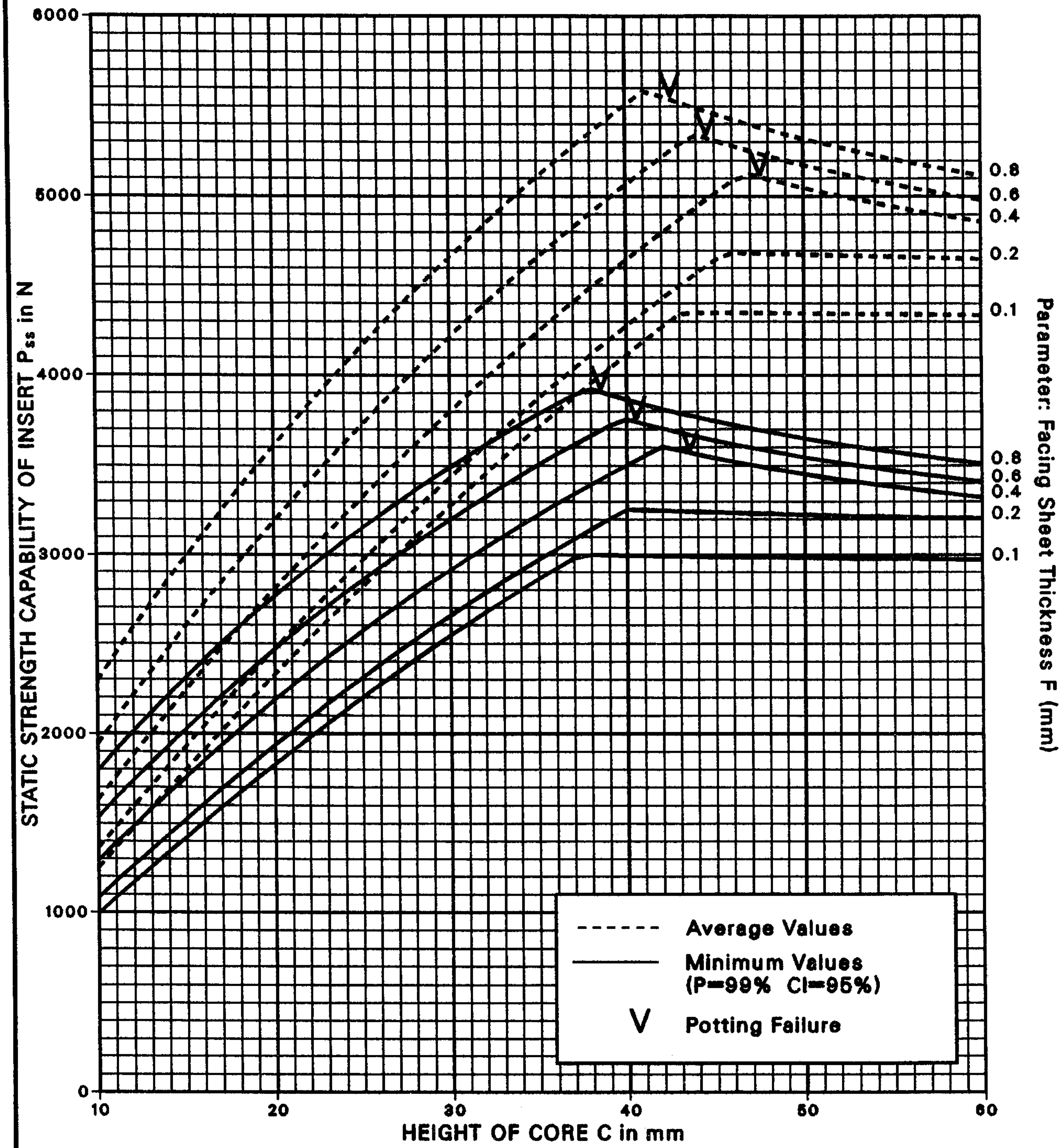


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Tension**

Insert Diameter: **17.5 mm**

Core : **1/8-5056-.0007**

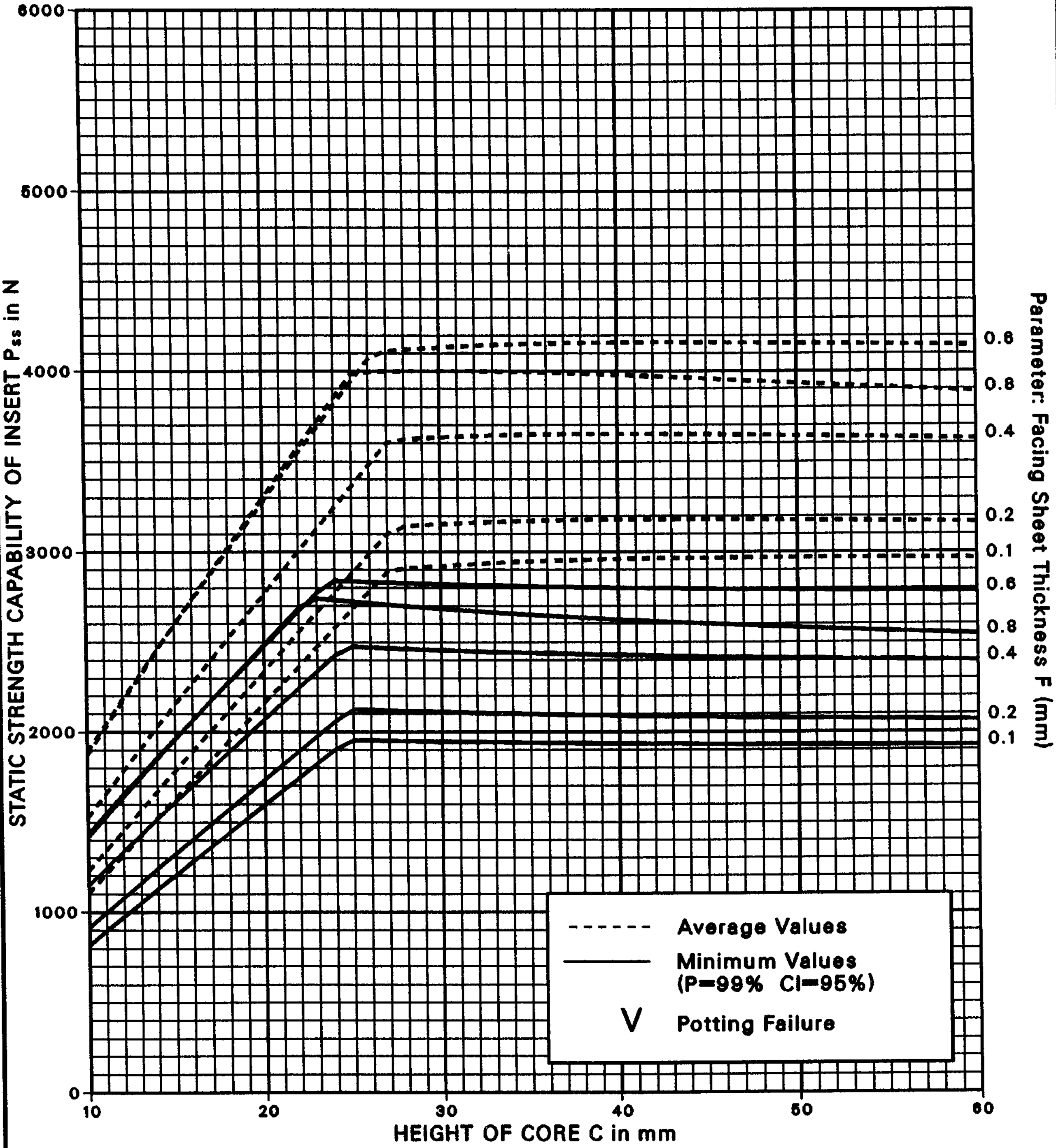


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Compression**

Insert Diameter: **17.5 mm**

Core : **1/8-5056-.0007**



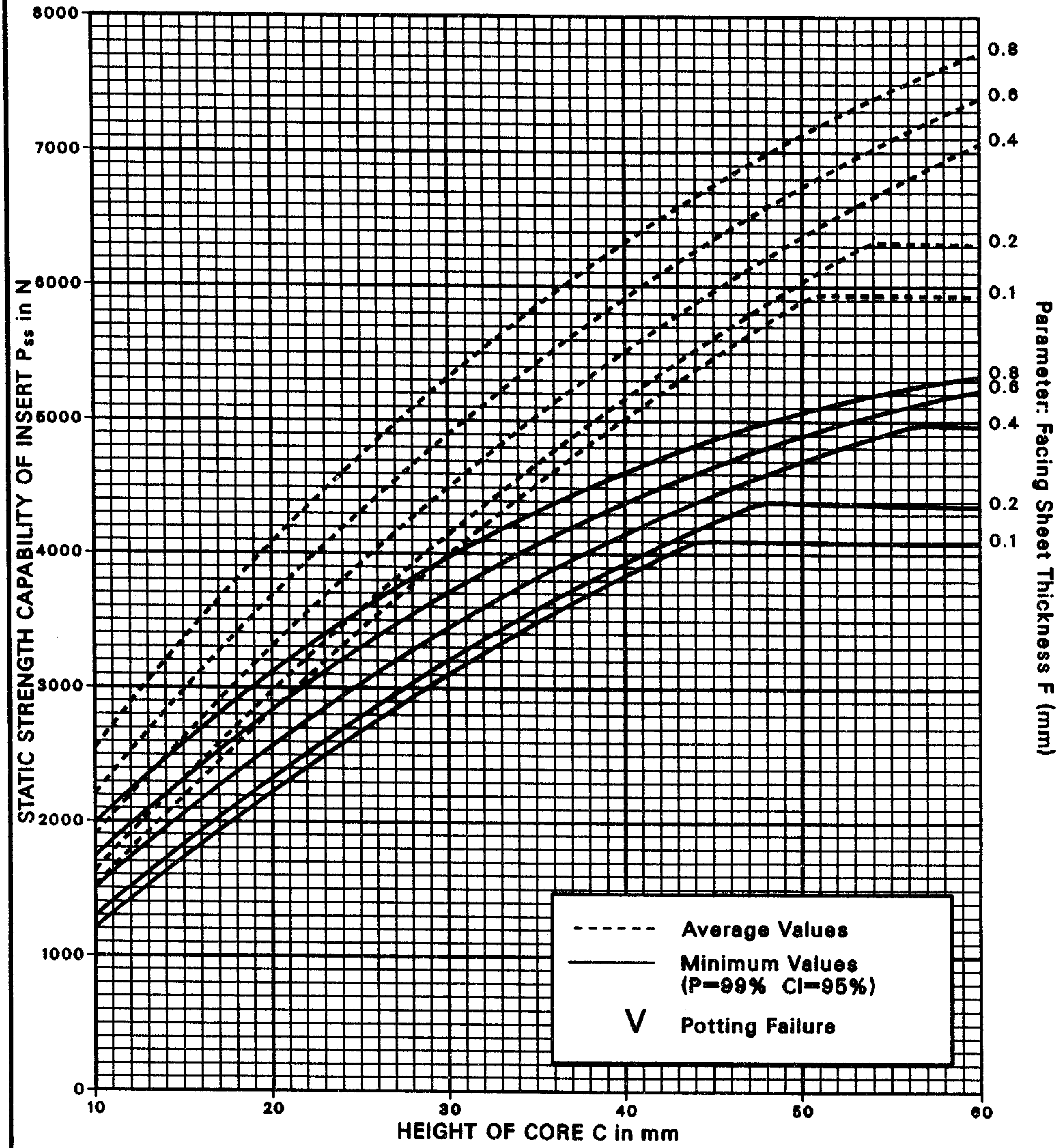
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **22.5 mm**

Core : **1/8-5056-.0007**

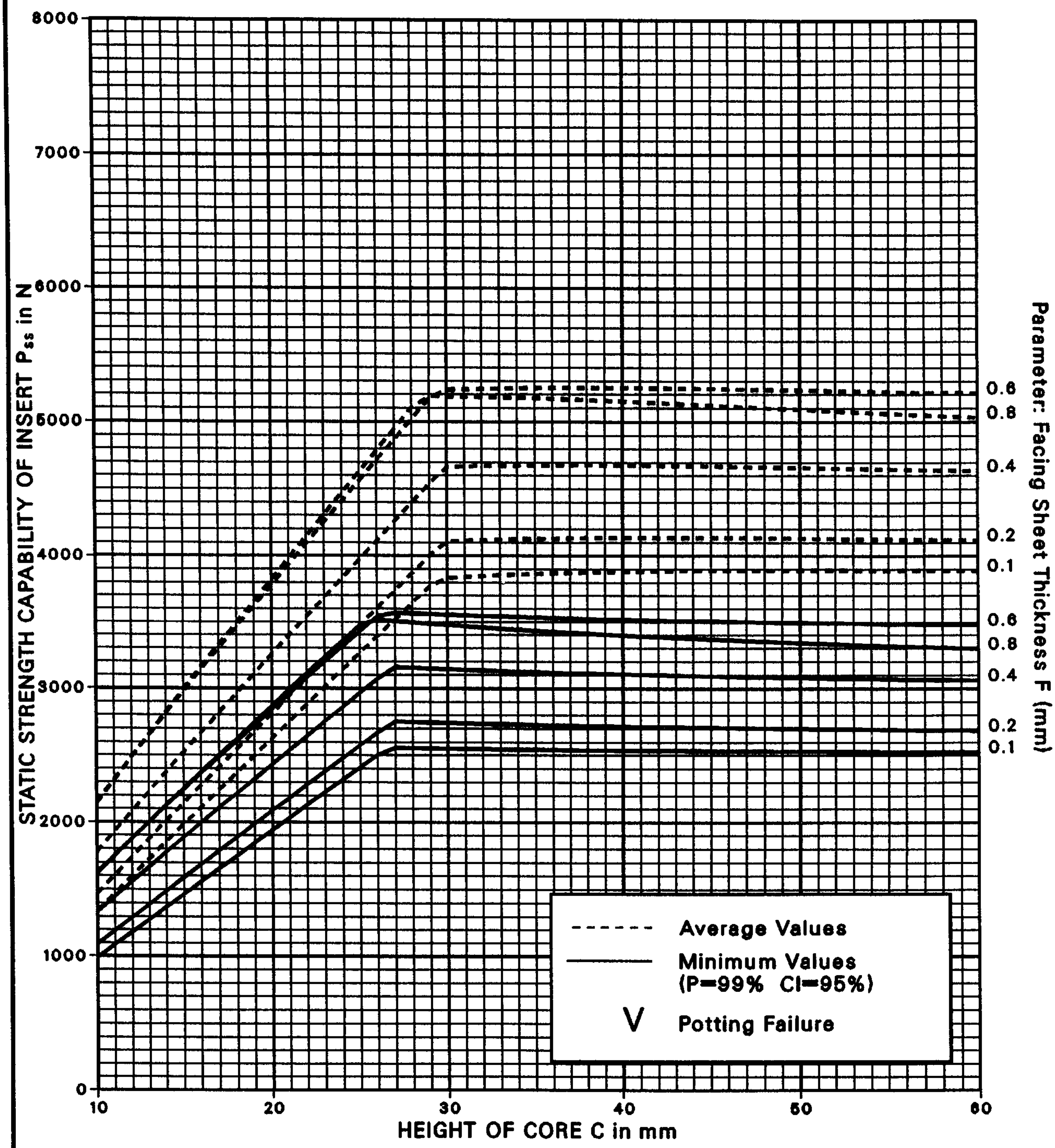


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 22.5 mm

Core : 1/8-5056-.0007



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8. 1/8 – 5056 – 0.001 Core

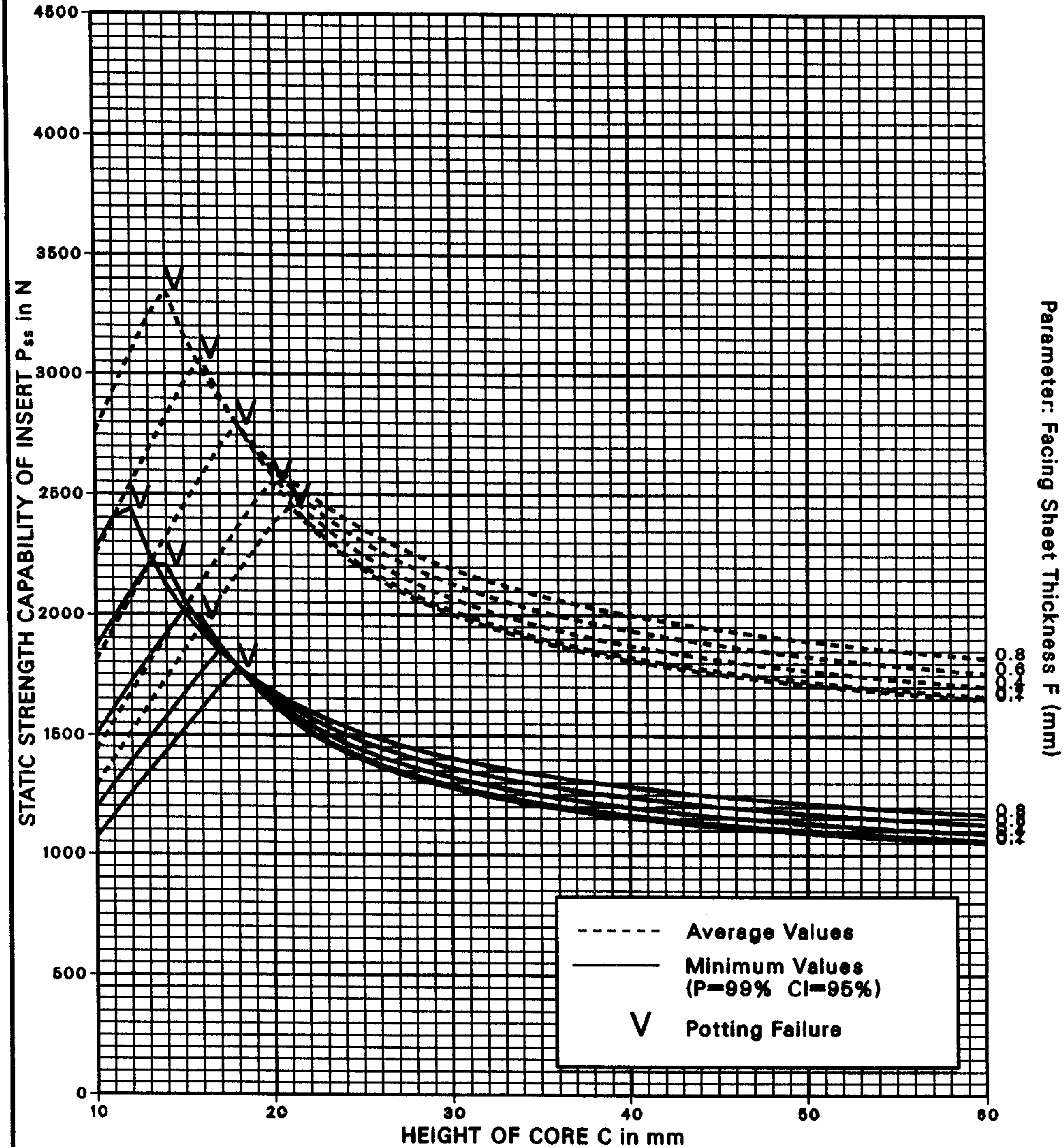
Insert Height h = 9 mm

Facing Material AL 2024

Load : Tension

Insert Diameter: 9.0 mm

Core : 1/8-5056-.001

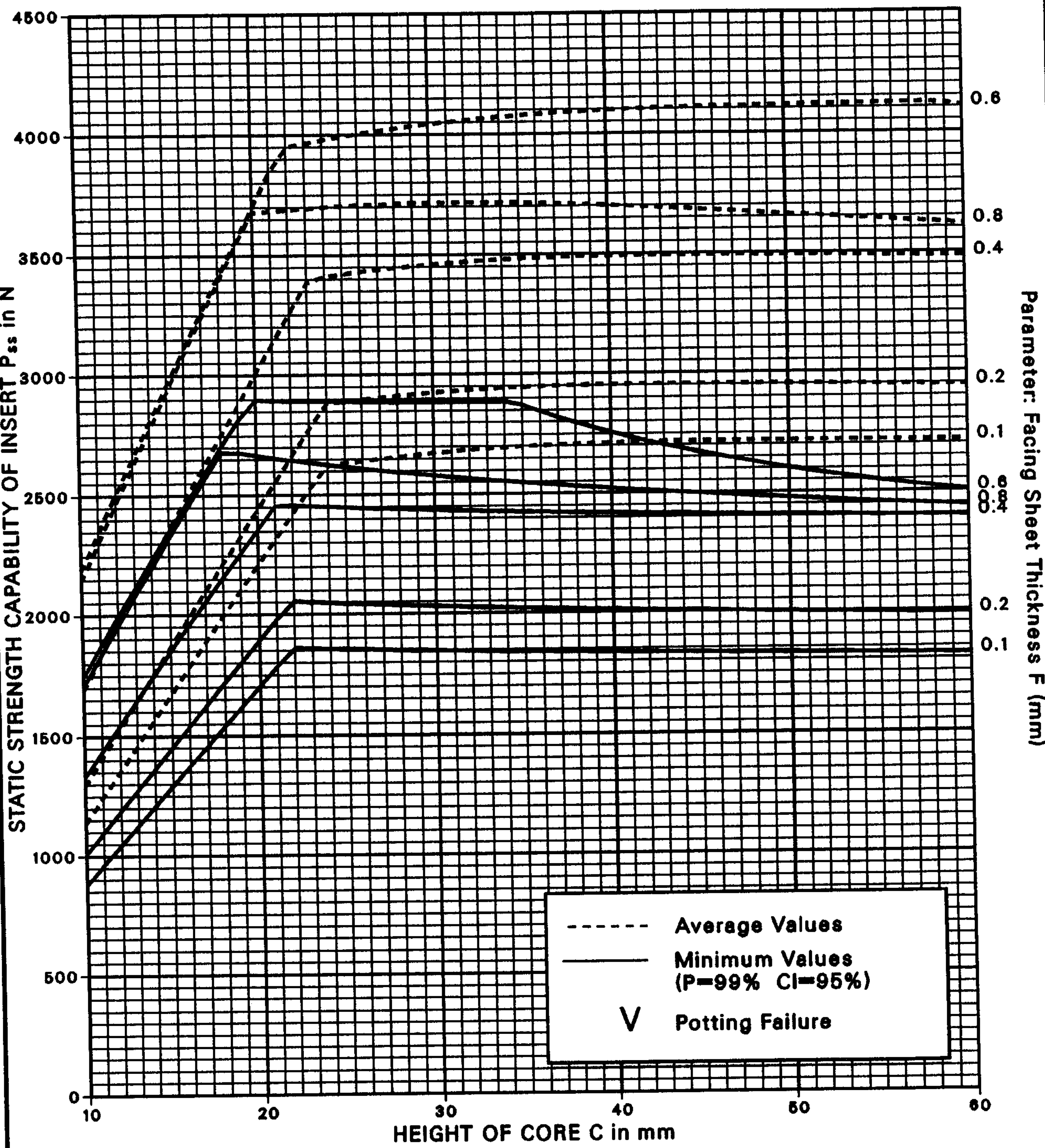


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 9.0 mm

Core : 1/8-5056-.001

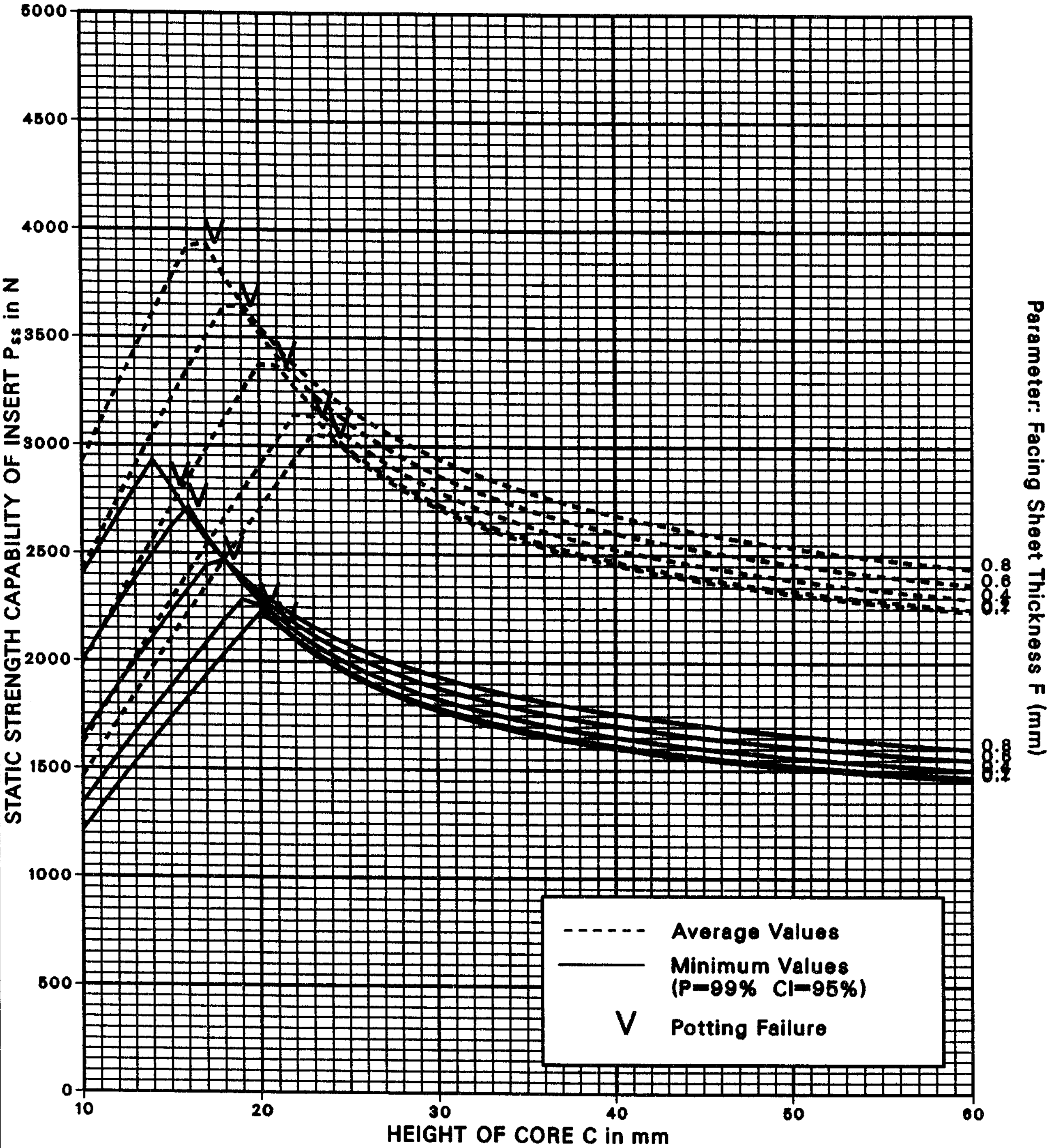


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **11.0 mm**

Core : **1/8-5056-.001**

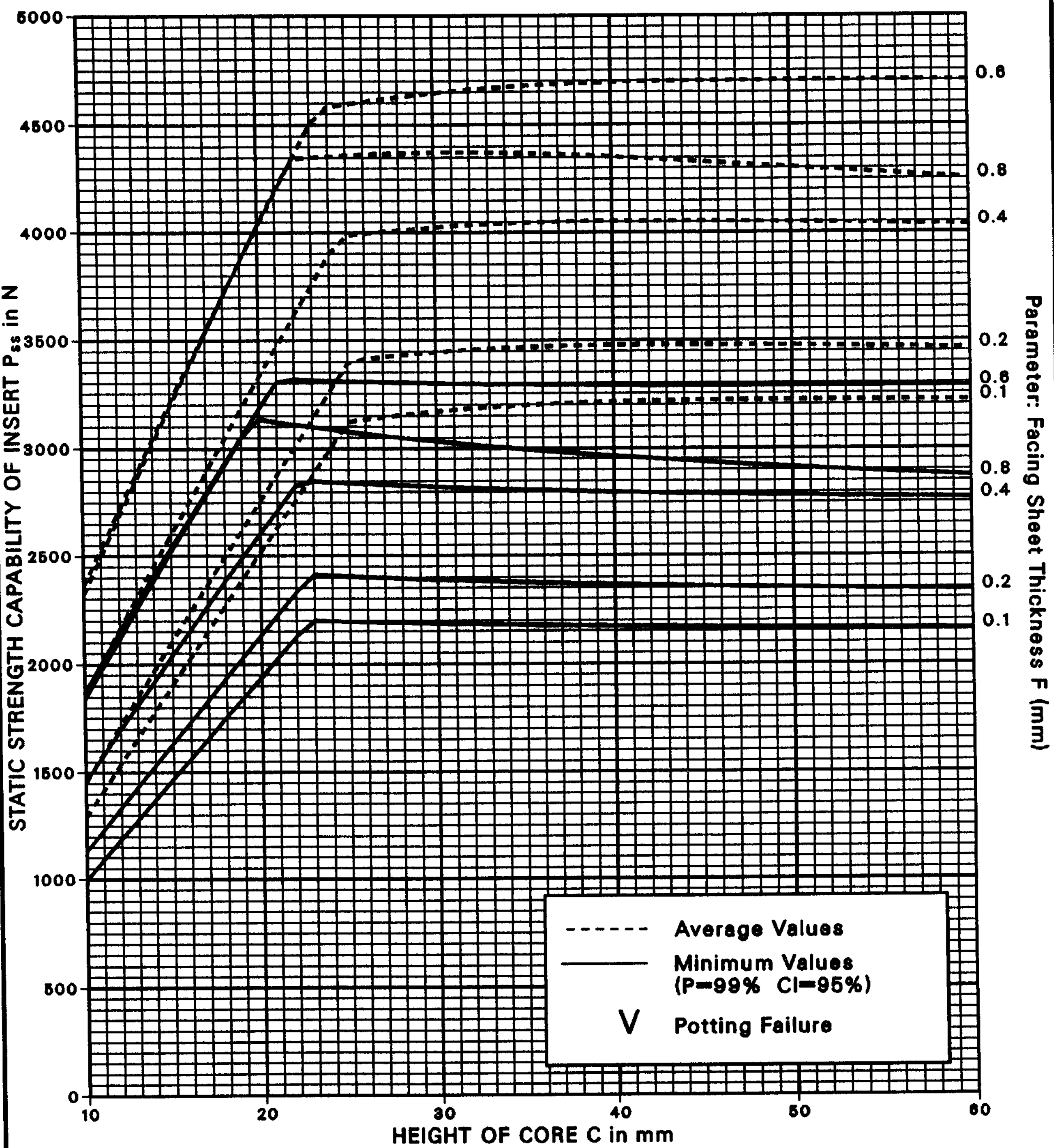


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 11.0 mm

Core : 1/8-5056-.001



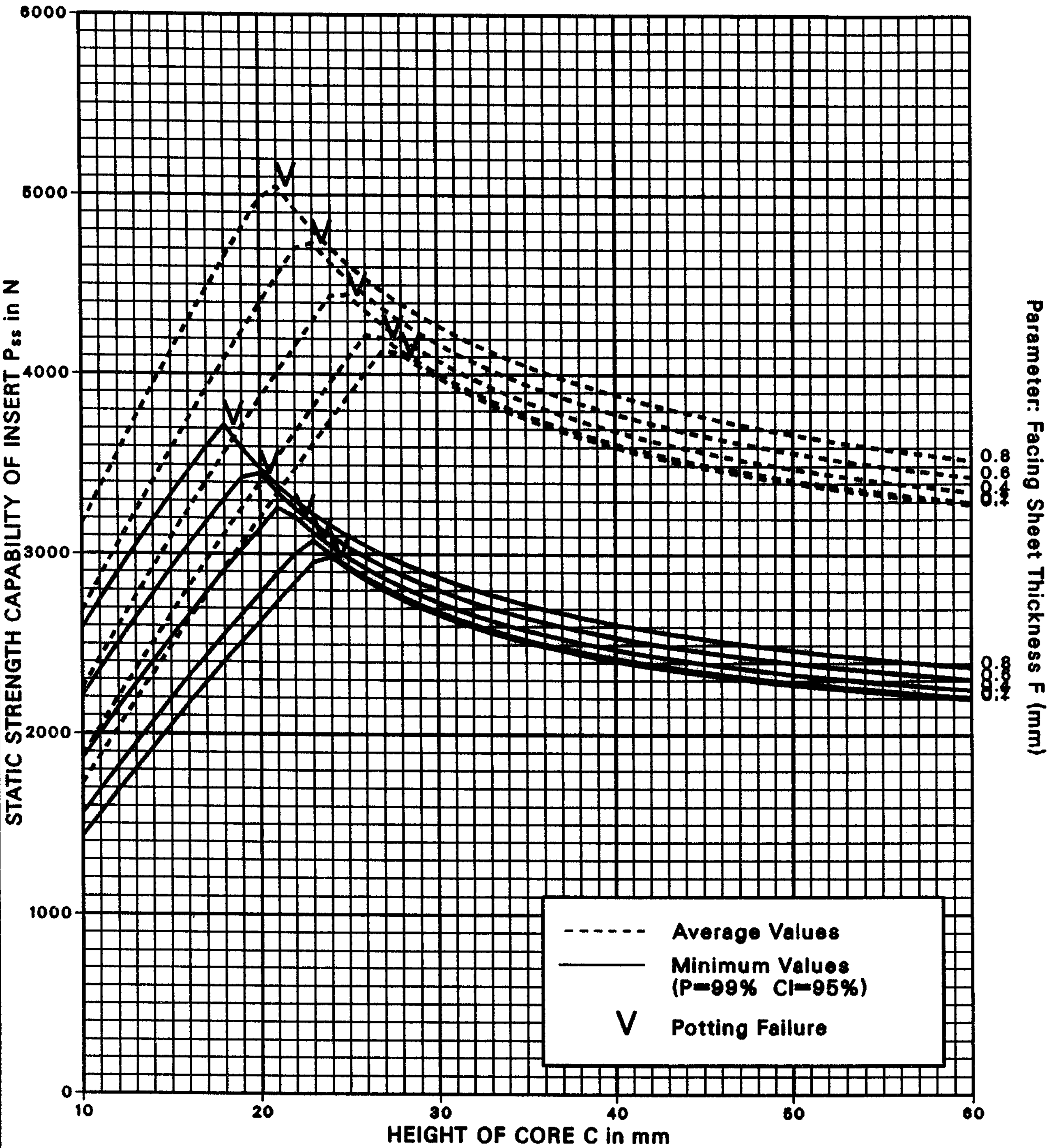
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **14.0 mm**

Core : **1/8-5056-.001**

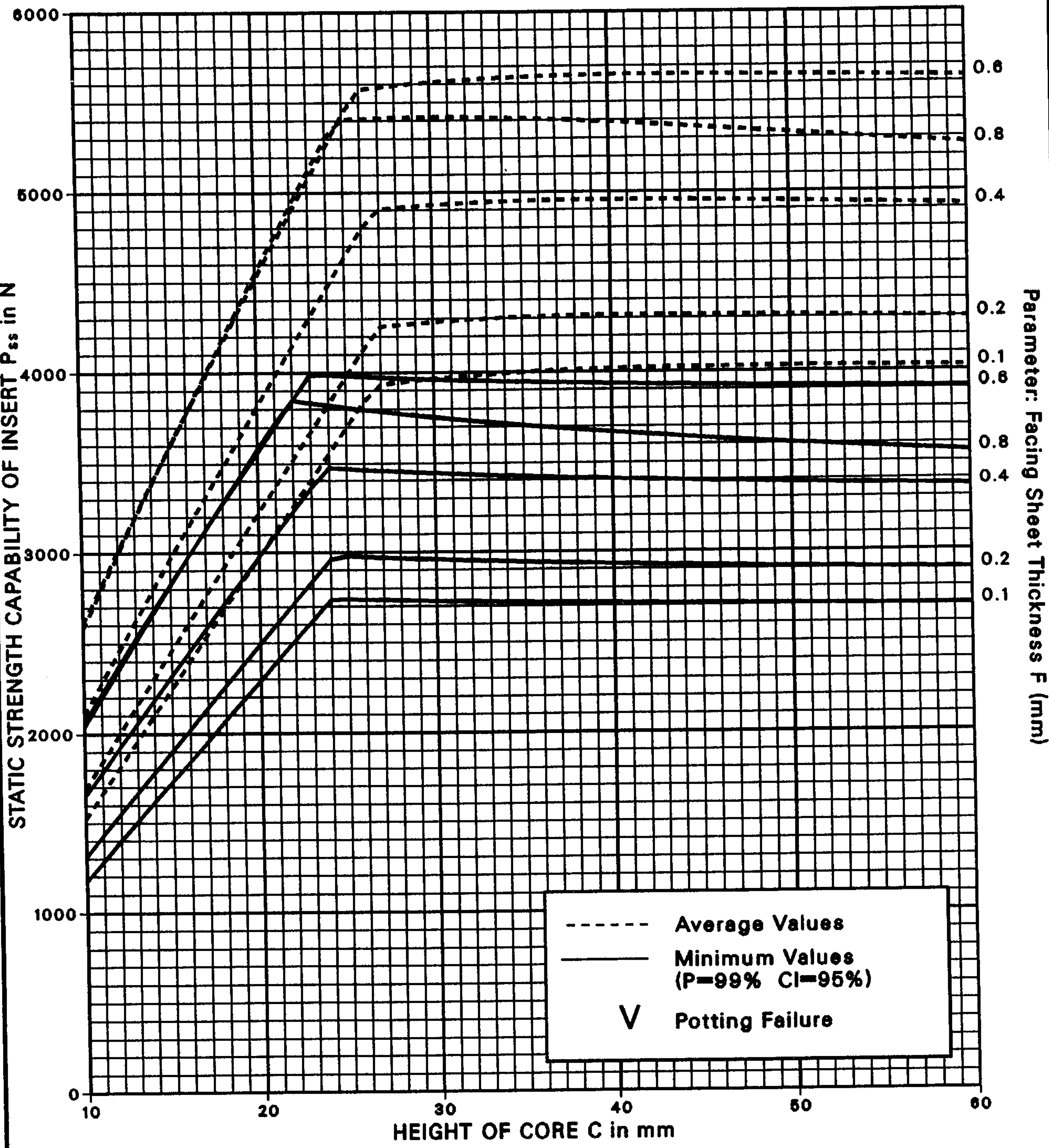


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 14.0 mm

Core : 1/8-5056-.001

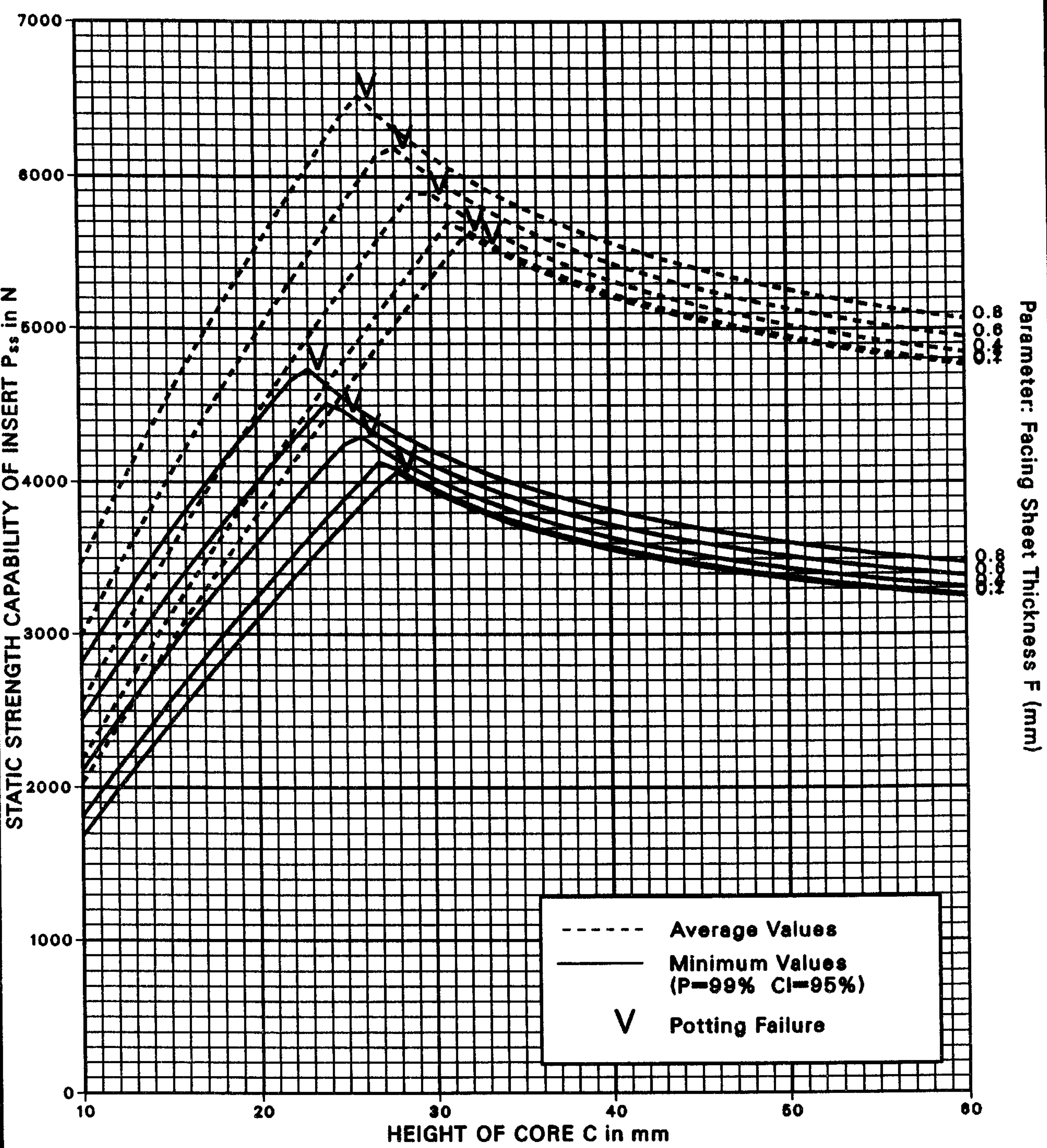


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **17.5 mm**

Core : **1/8-5056-.001**



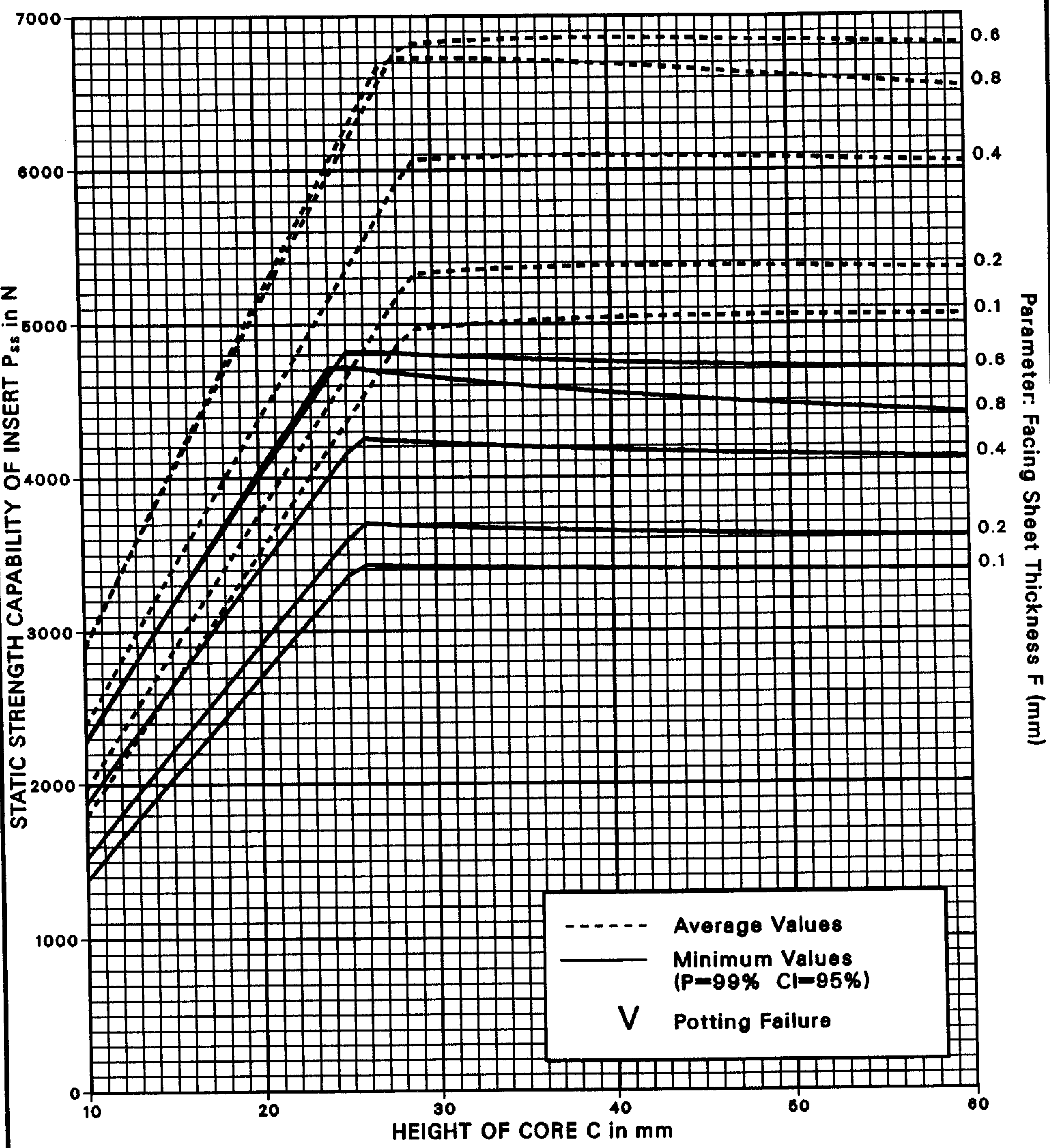
Version 2.0

Insert Height h = 9 mm	Facing Material AL 2024

Load : **Compression**

Insert Diameter: **17.5 mm**

Core : **1/8-5056-.001**

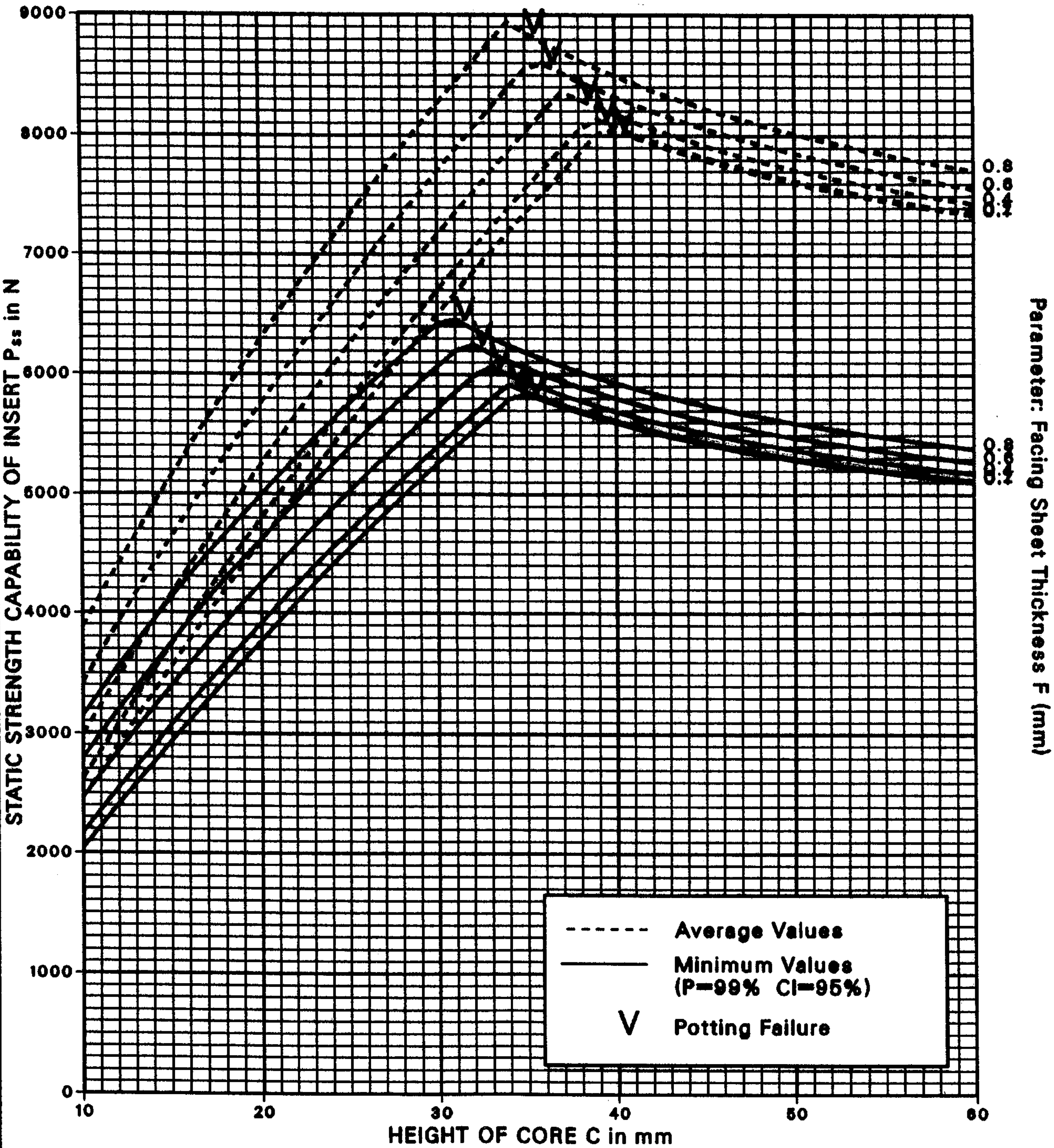


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **22.5 mm**

Core : **1/8-5056-.001**

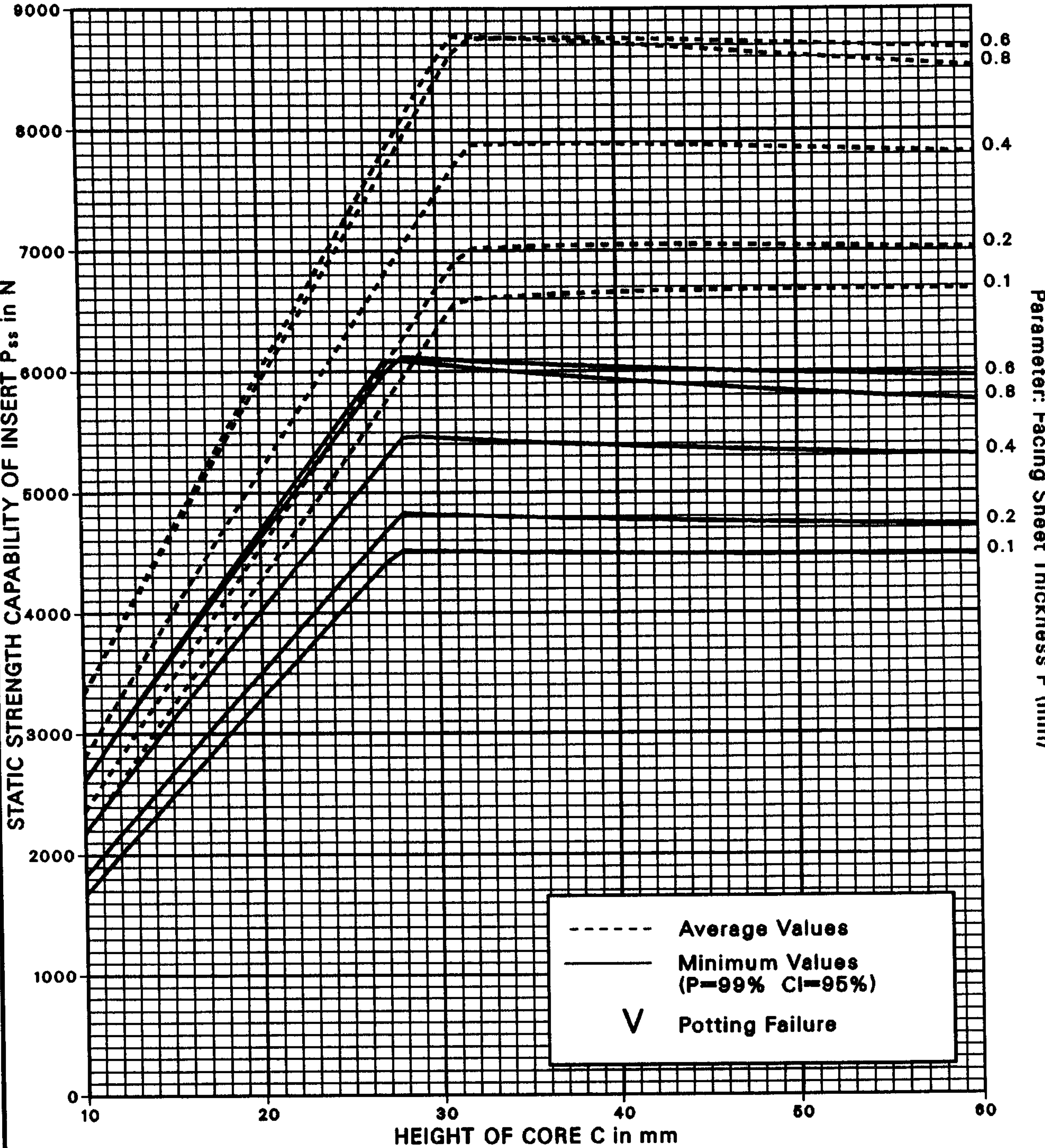


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 22.5 mm

Core : 1/8-5056-.001



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9. HRH 10 – 3/16 – 2.0 Core

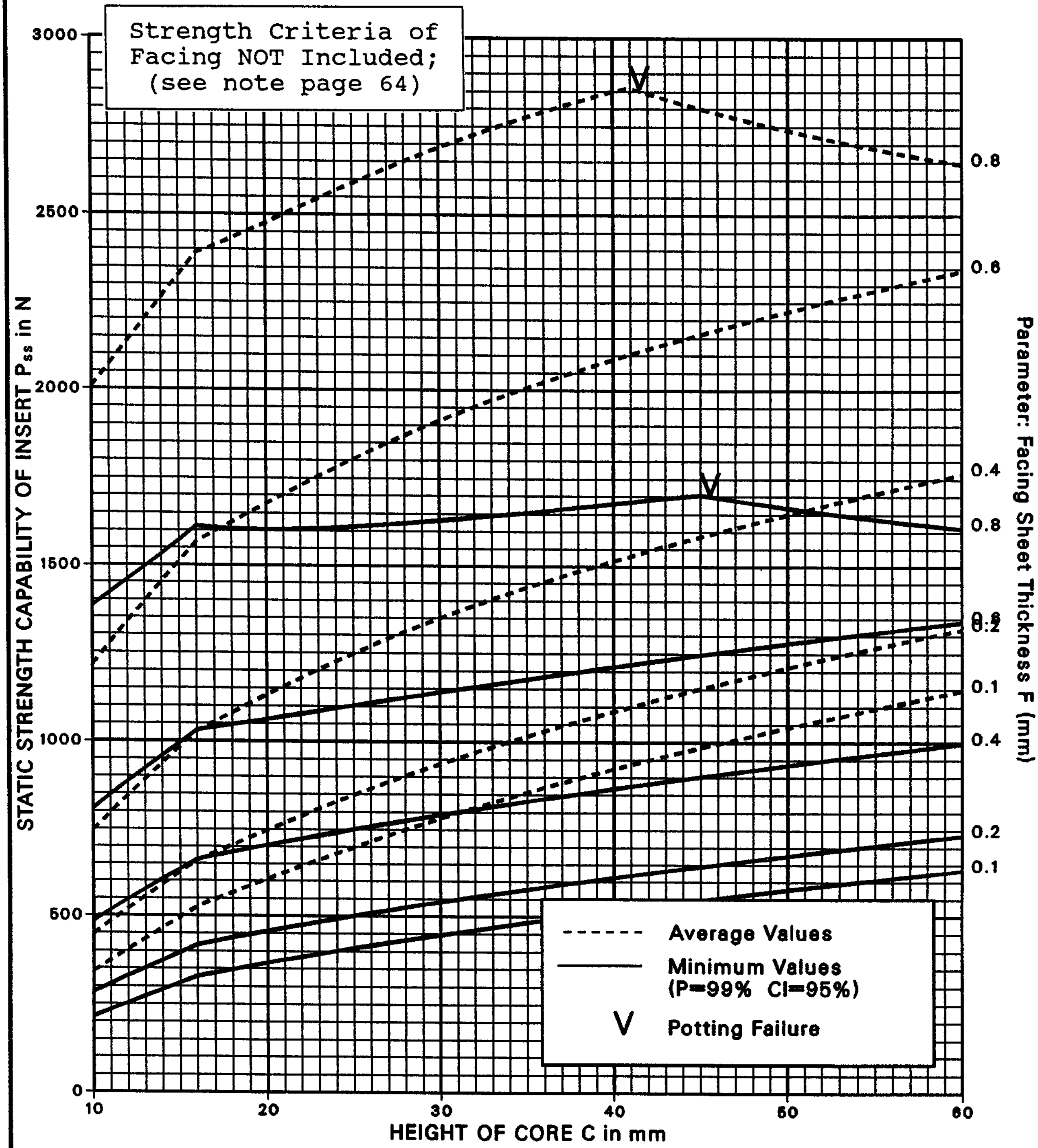
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **9.0 mm**

Core : **HRH 10-3/16-2.0**

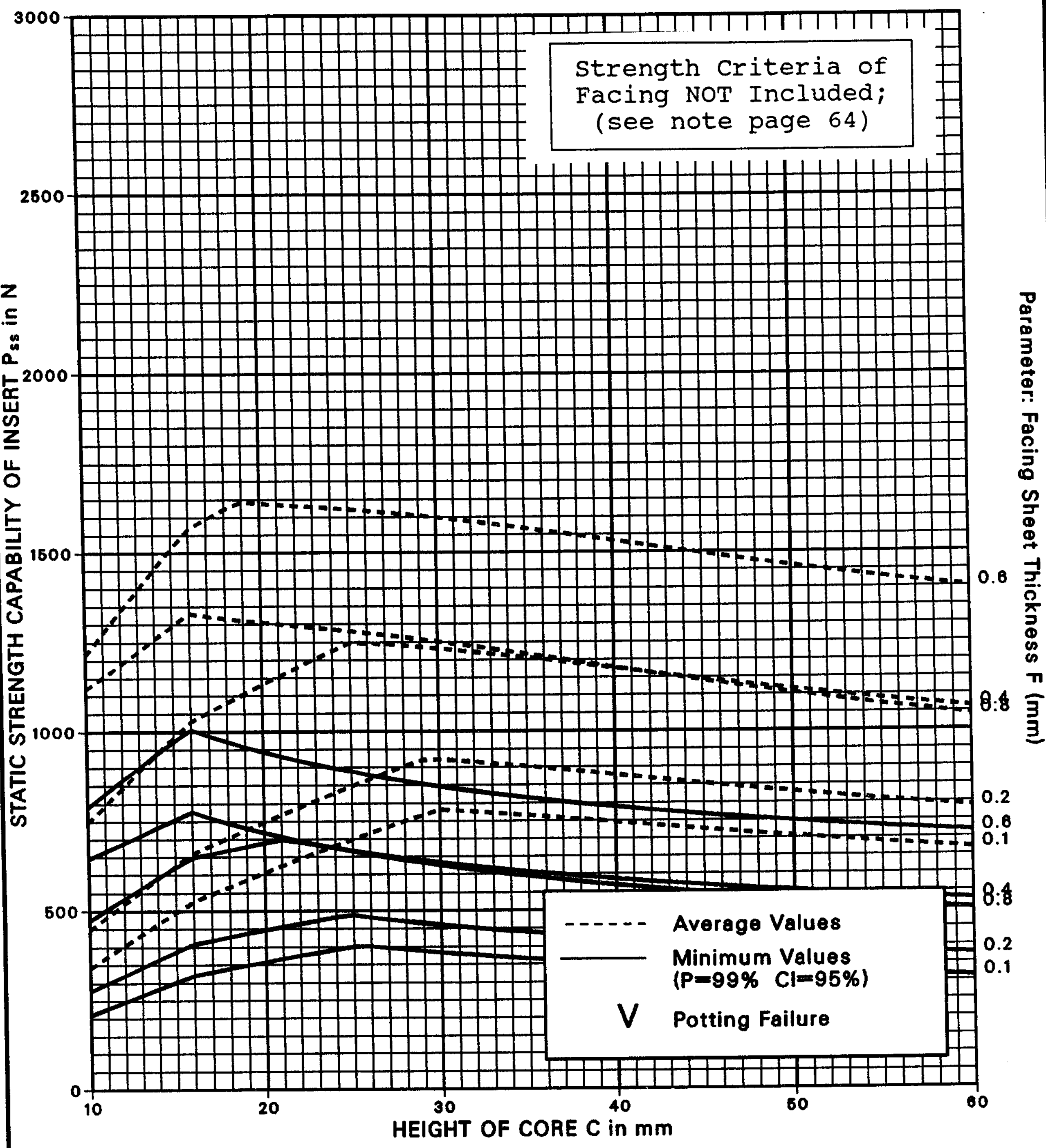


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Compression**

Insert Diameter: **9.0 mm**

Core : **HRH 10-3/16-2.0**

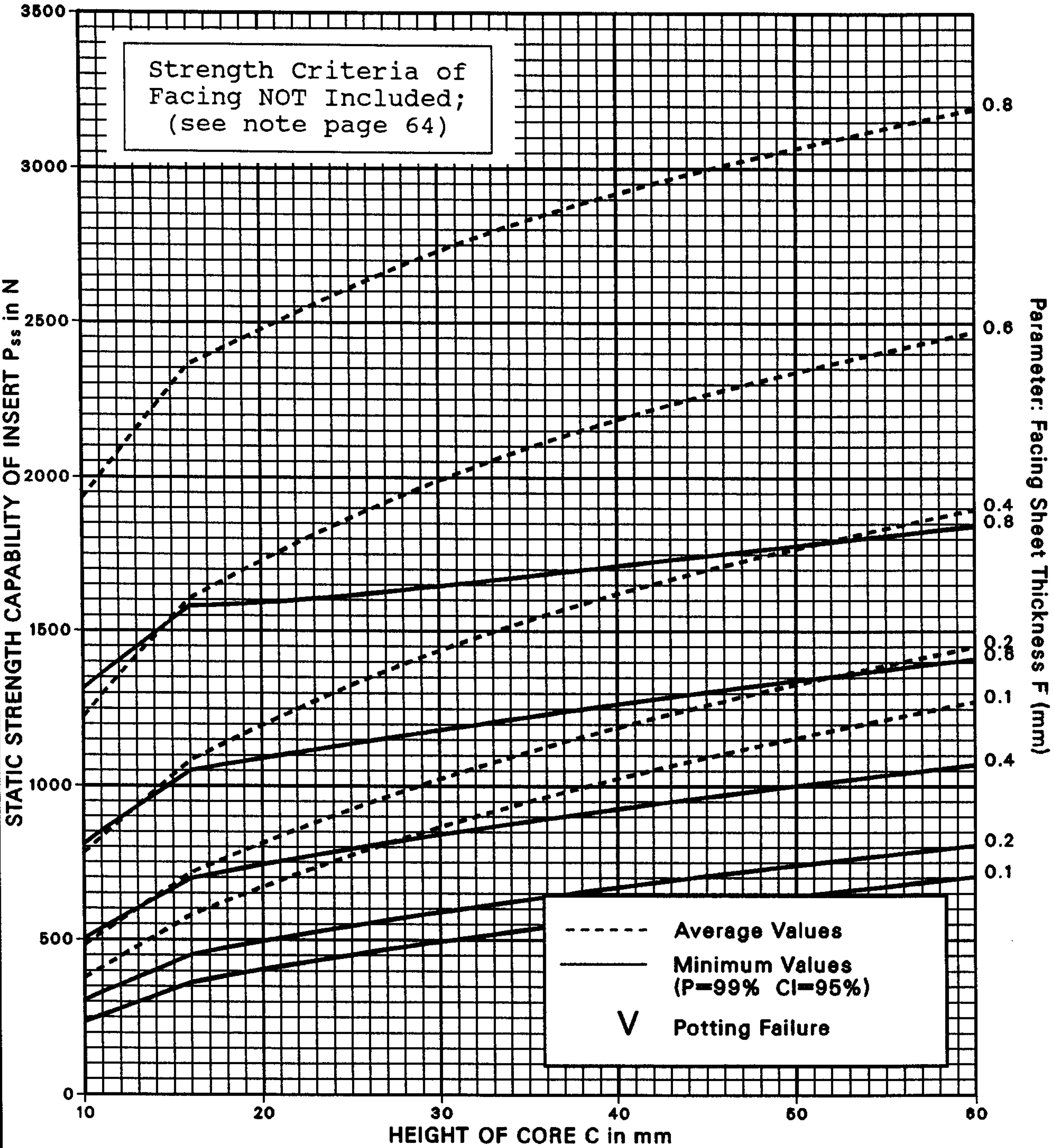


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **11.0 mm**

Core : **HRH 10-3/16-2.0**

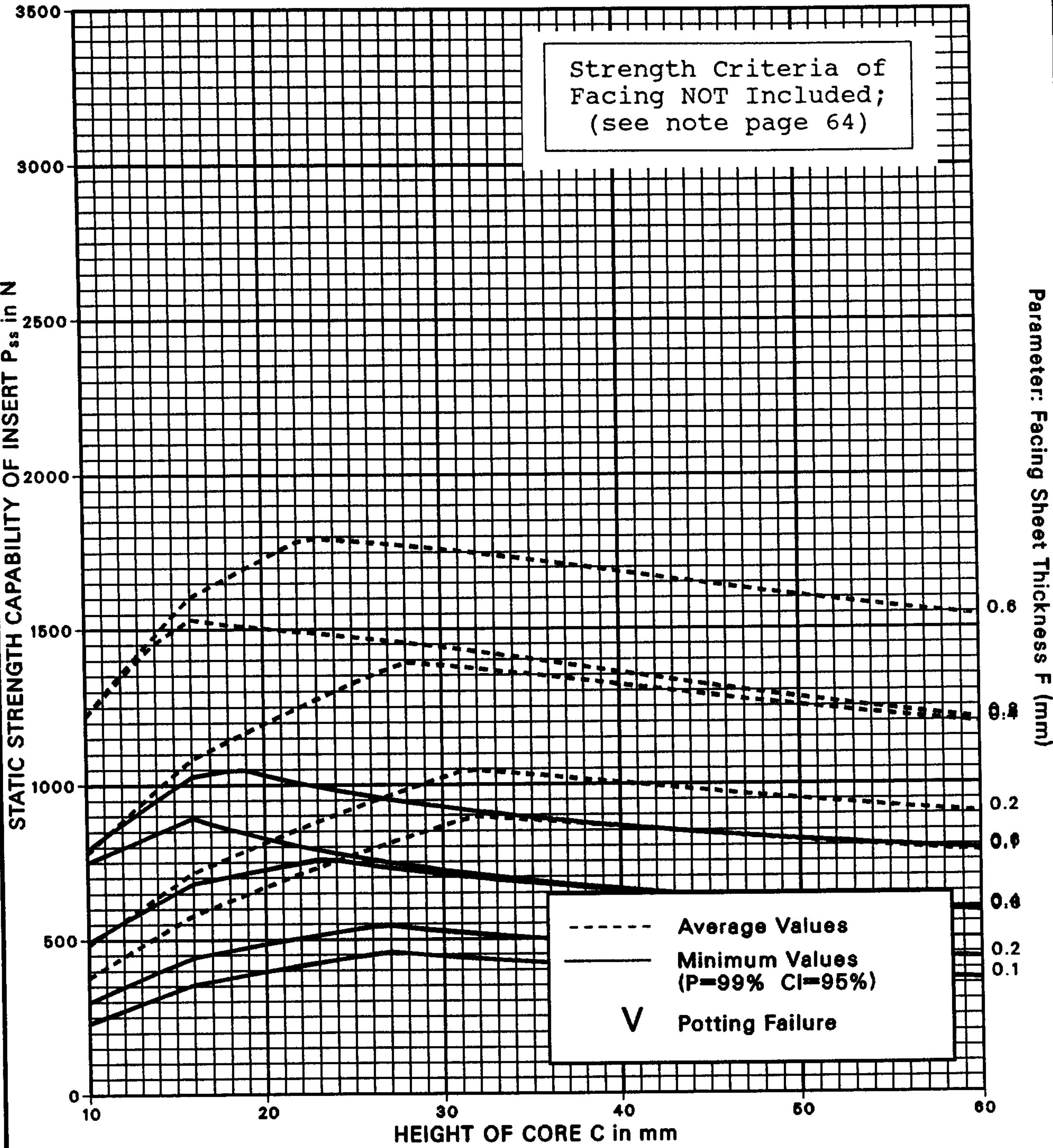


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 11.0 mm

Core : HRH 10-3/16-2.0



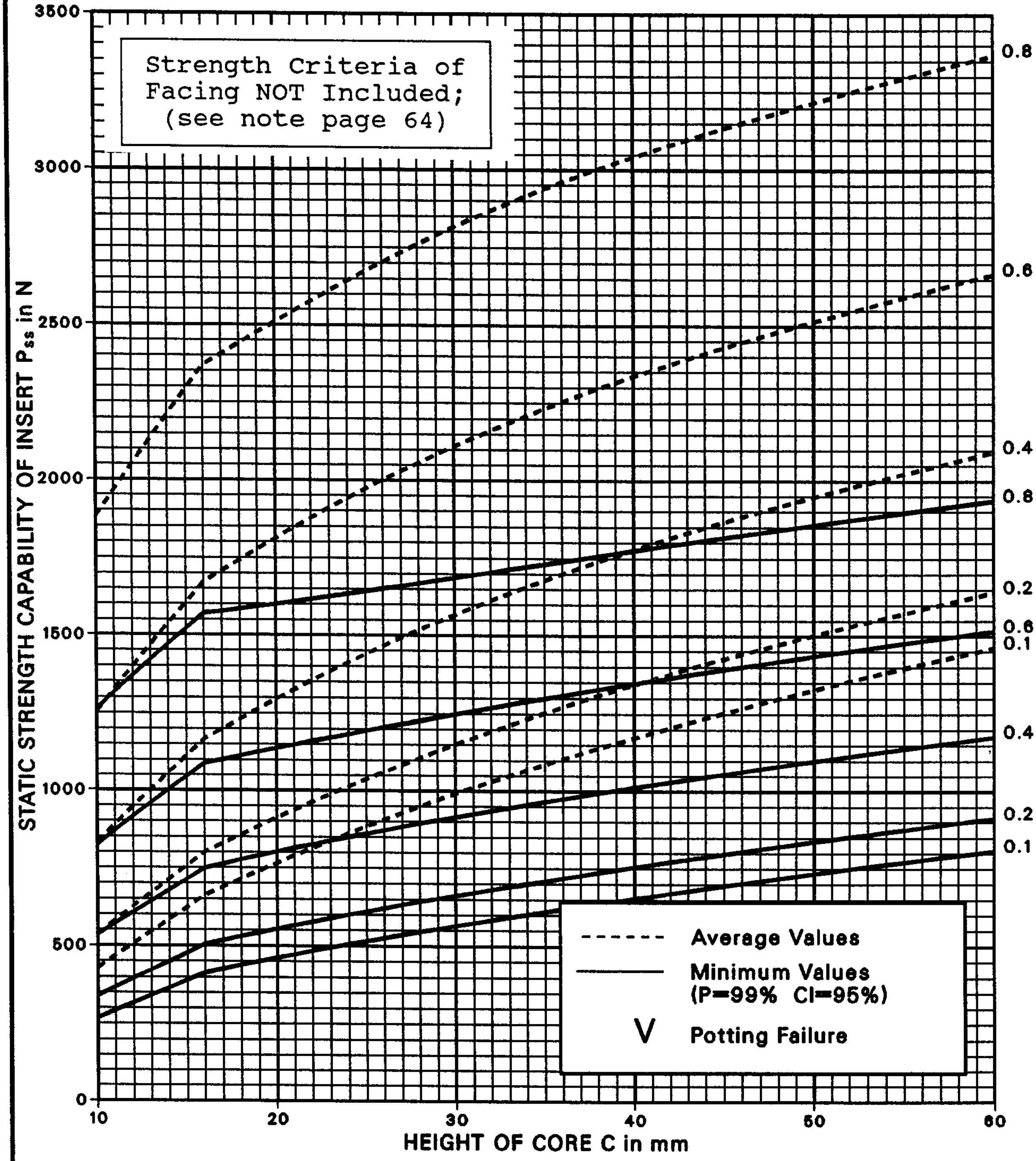
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **14.0 mm**

Core : **HRH 10-3/16-2.0**

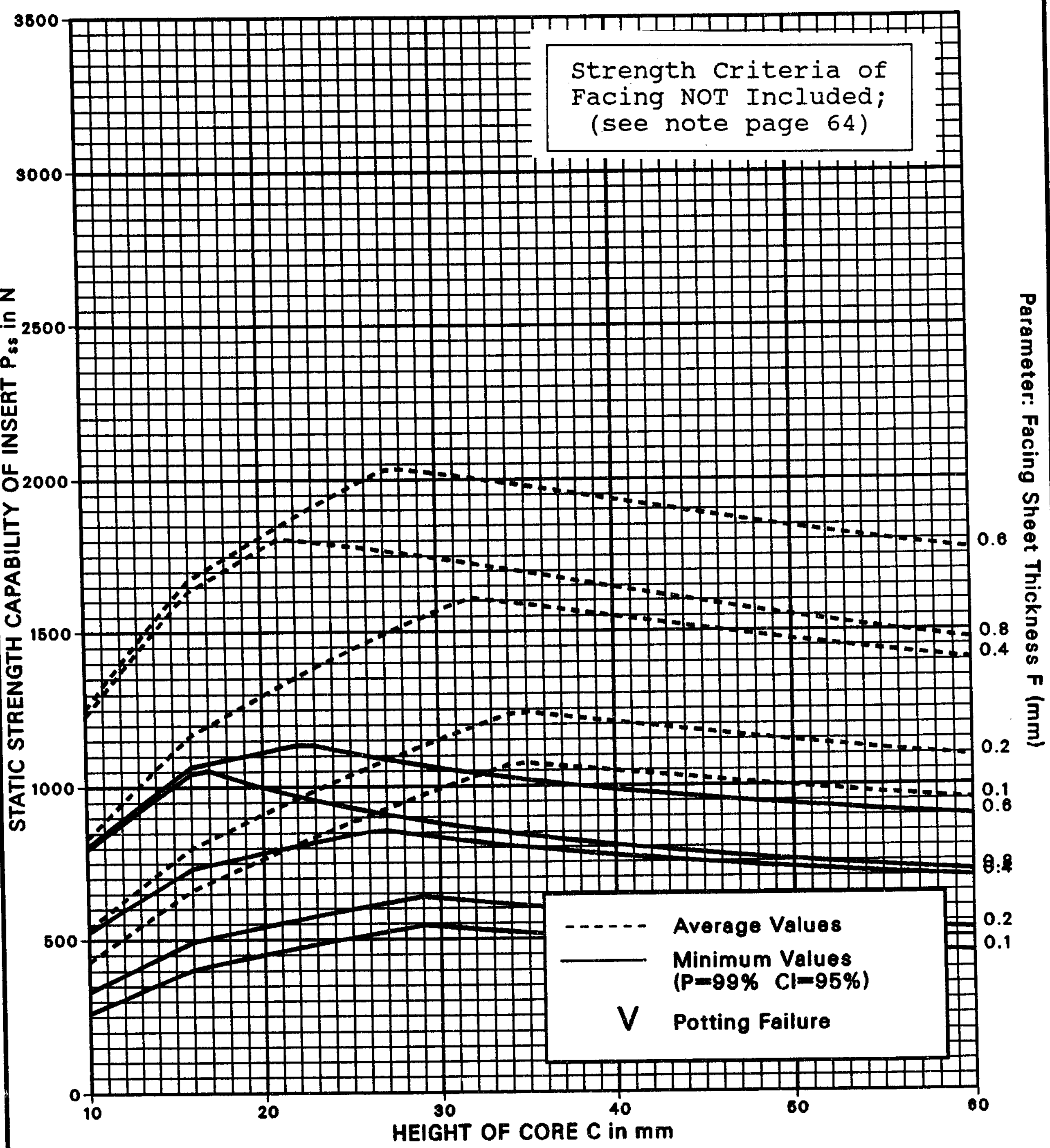


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 14.0 mm

Core : HRH 10-3/16-2.0

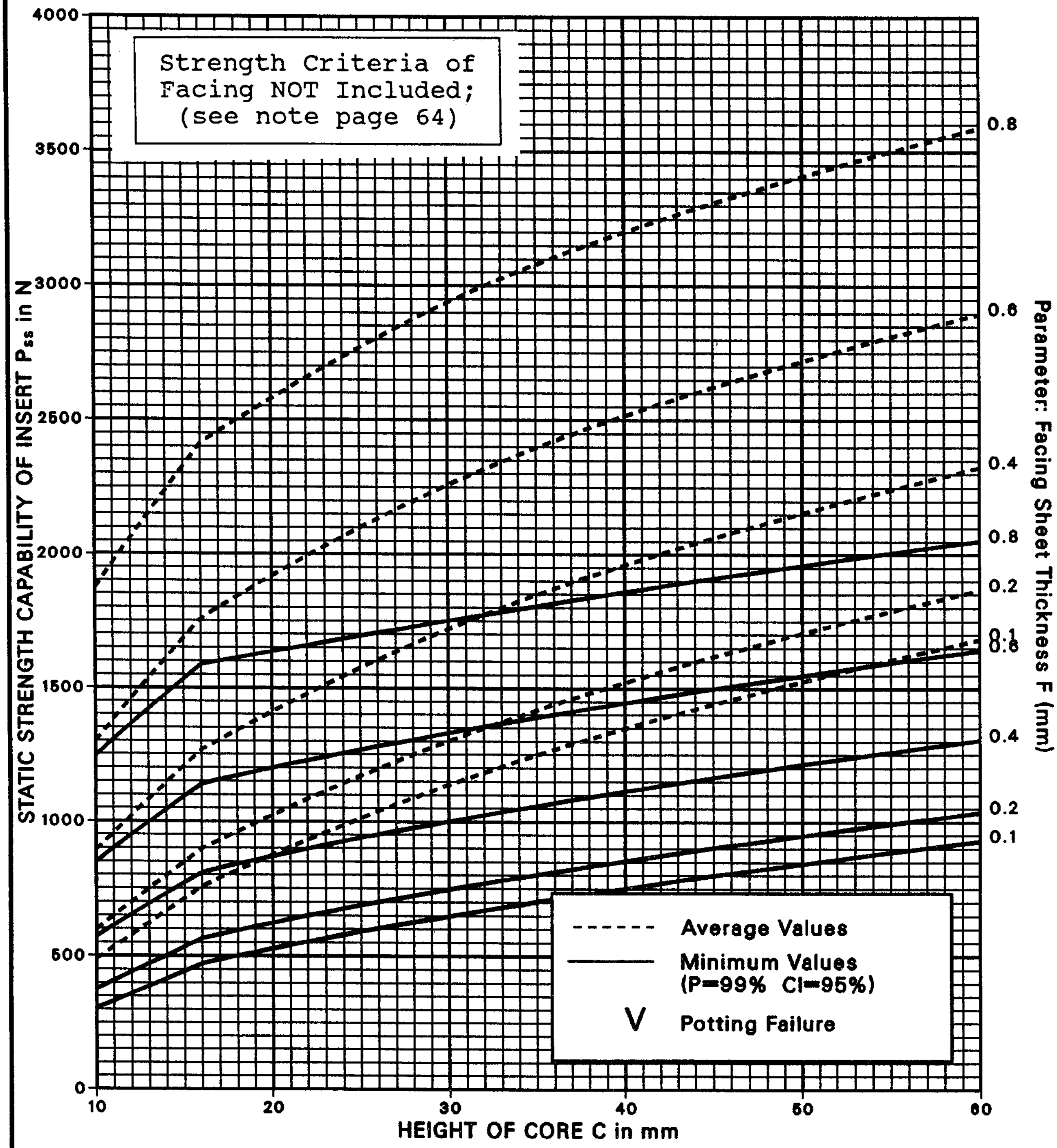


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **17.5 mm**

Core : **HRH 10-3/16-2.0**

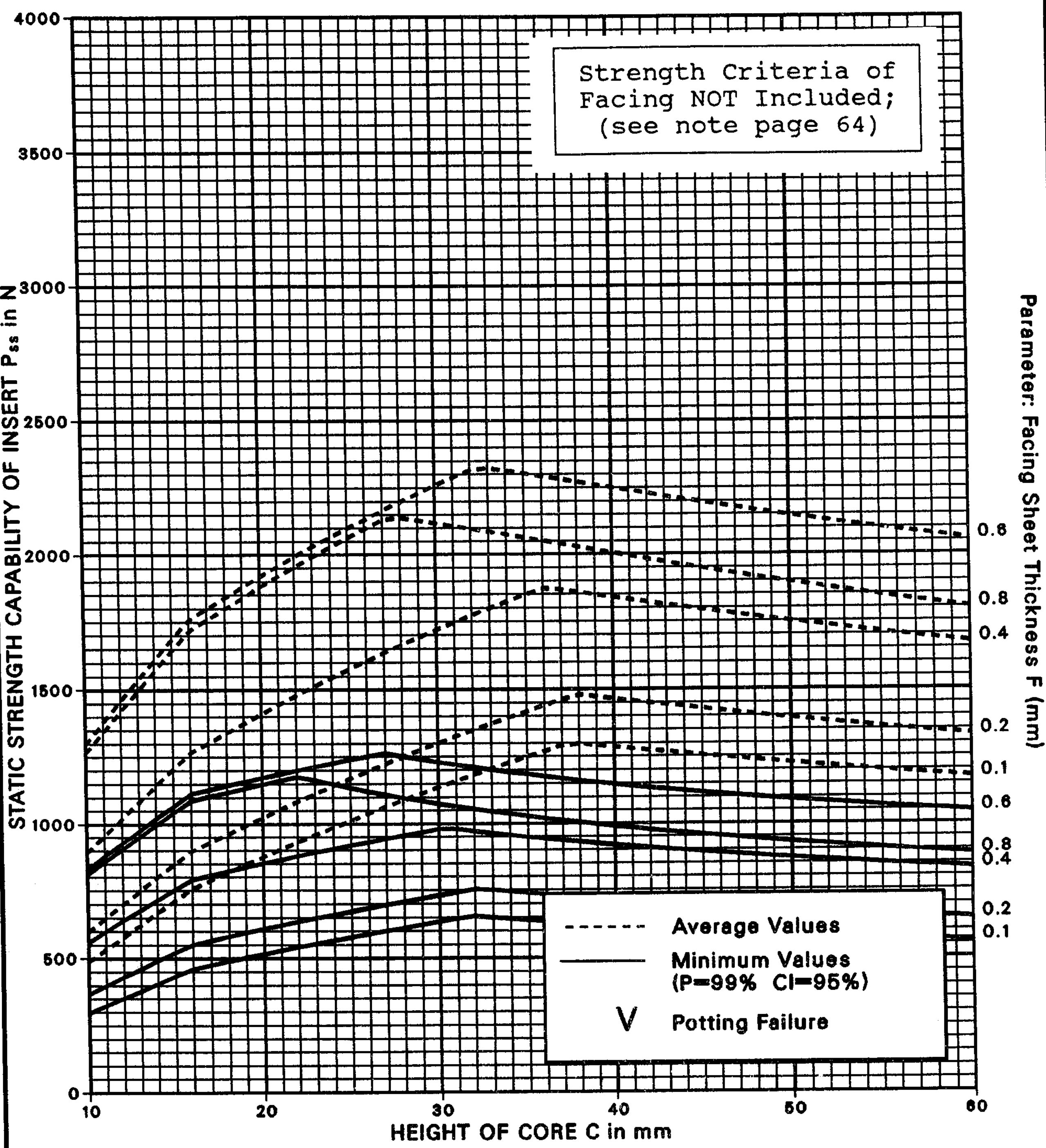


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 17.5 mm

Core : HRH 10-3/16-2.0

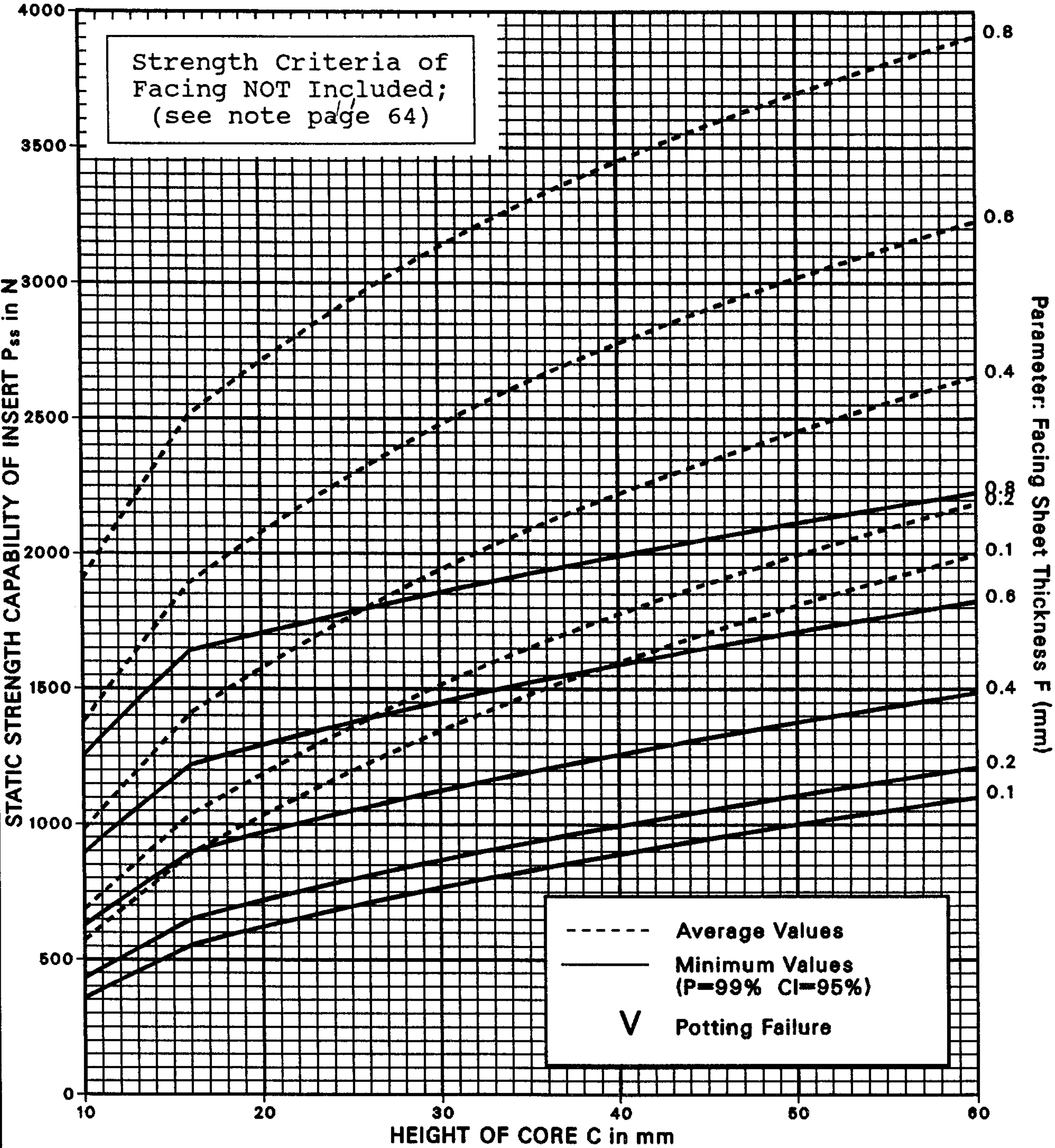


Insert Height h = 9 mm   Facing Material AL 2024

Load : **Tension**

Insert Diameter: **22.5 mm**

Core : **HRH 10-3/16-2.0**

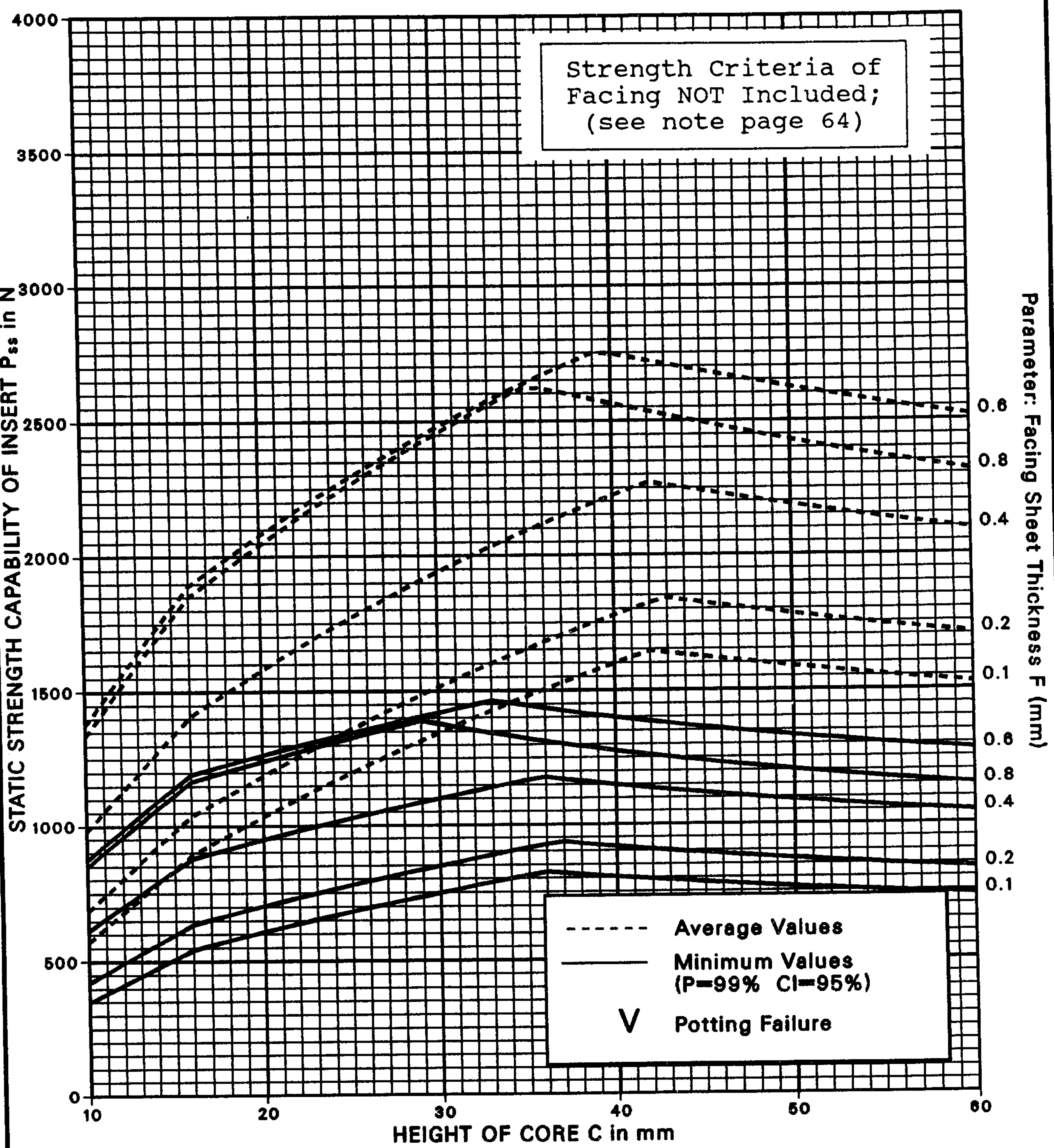


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 22.5 mm

Core : HRH 10-3/16-2.0



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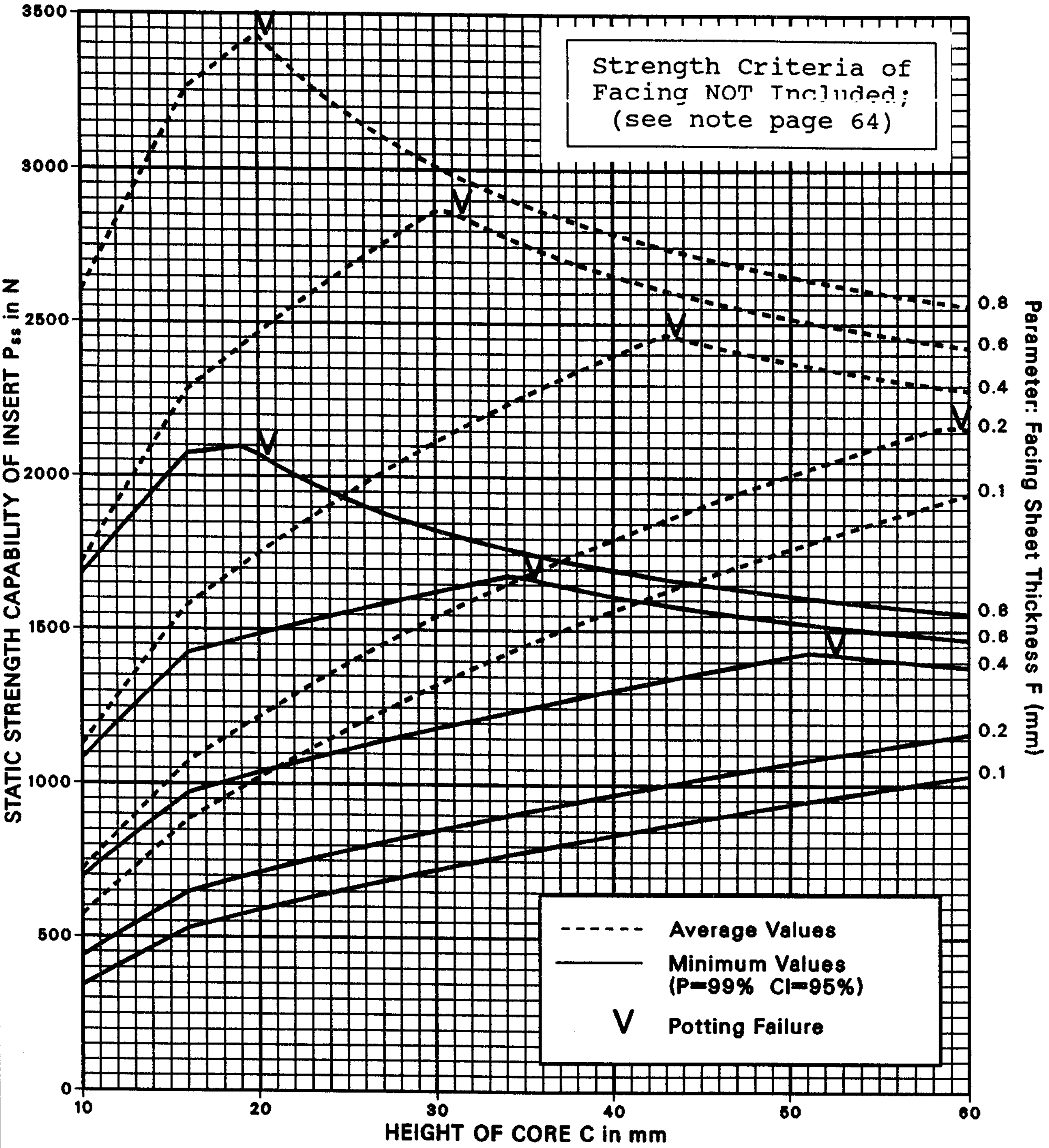
10. HRH 10 – 3/16 – 3.0 Core

Insert Height h = 9 mm | Facing Material AL 2024

Load : Tension

Insert Diameter: 9.0 mm

Core : HRH 10-3/16-3.0

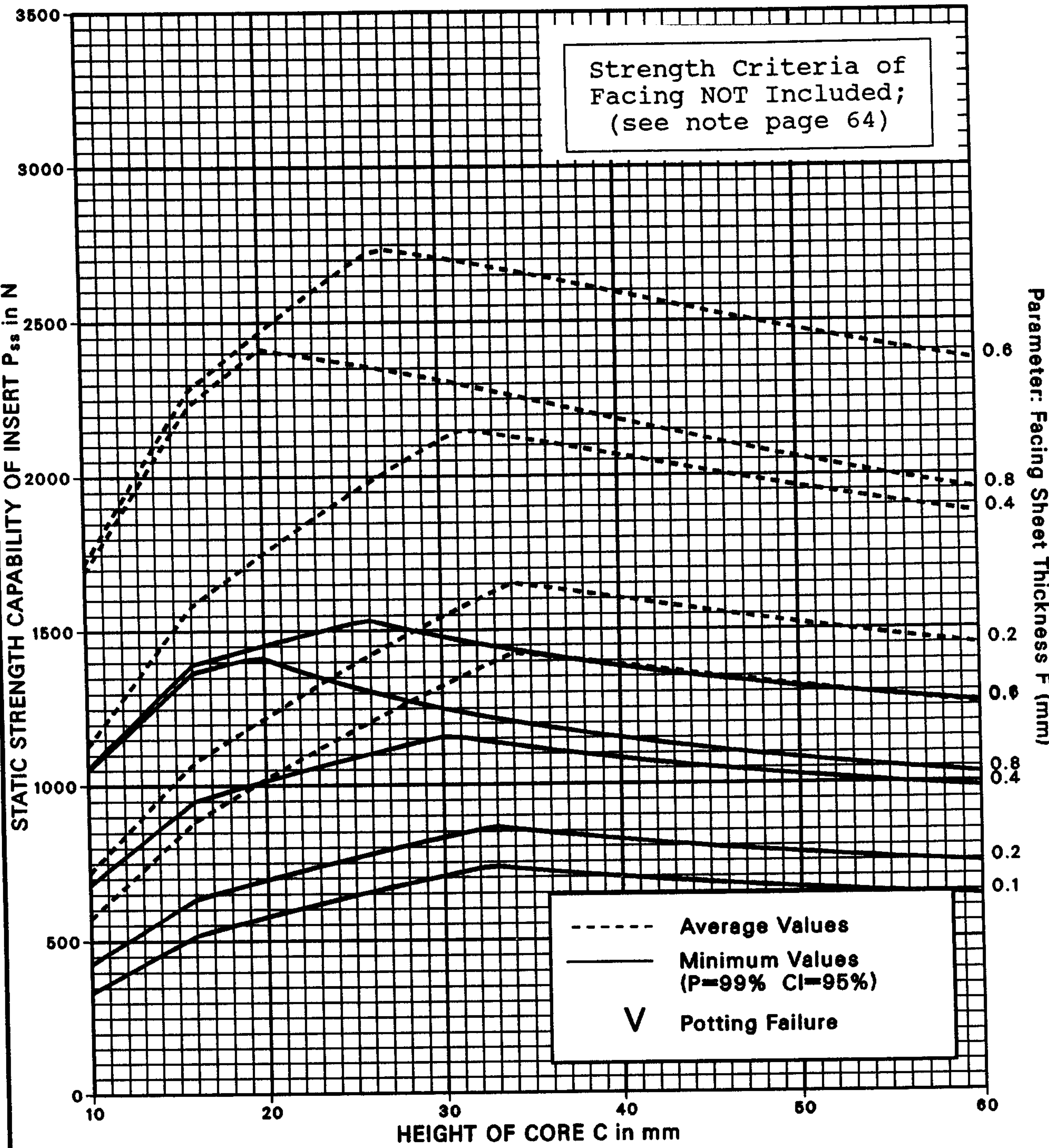


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Compression**

Insert Diameter: **9.0 mm**

Core : **HRH 10-3/16-3.0**



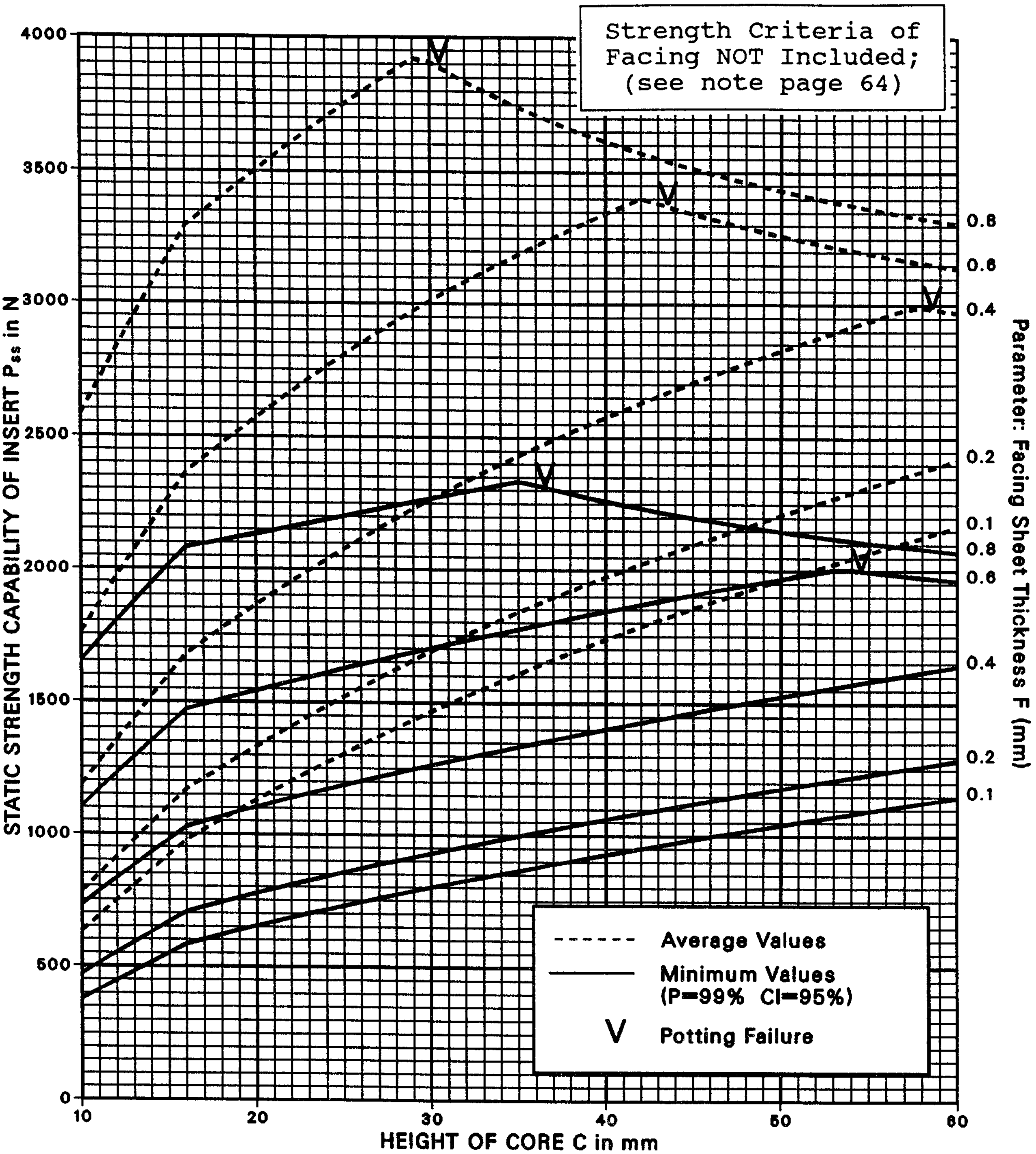
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **11.0 mm**

Core : **HRH 10-3/16-3.0**



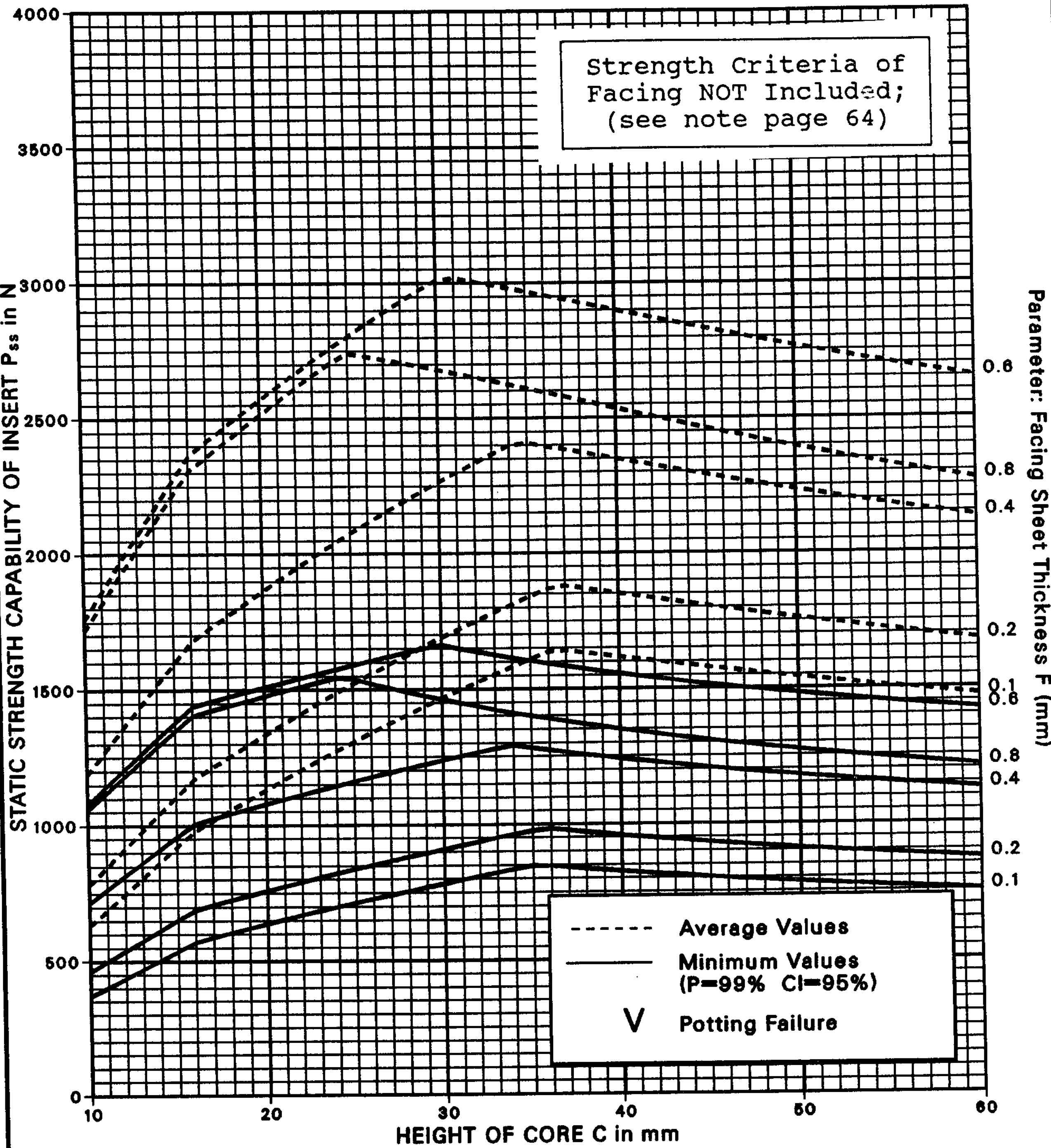
Insert Height h = 9 mm

Facing Material AL 2024

Load : Compression

Insert Diameter: 11.0 mm

Core : HRH 10-3/16-3.0

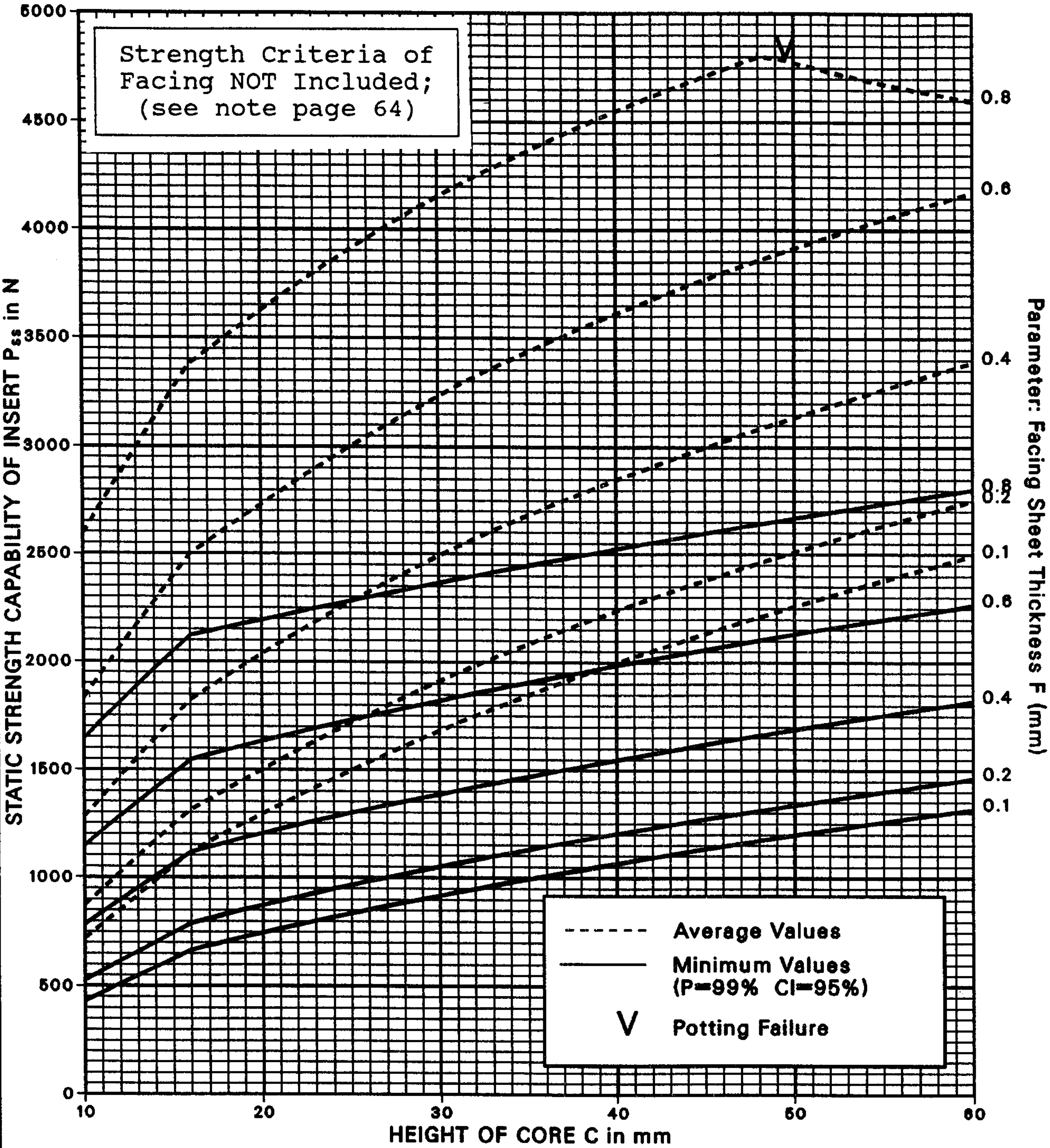


Insert Height h = 9 mm — Facing Material AL 2024

Load : **Tension**

Insert Diameter: **14.0 mm**

Core : **HRH 10-3/16-3.0**

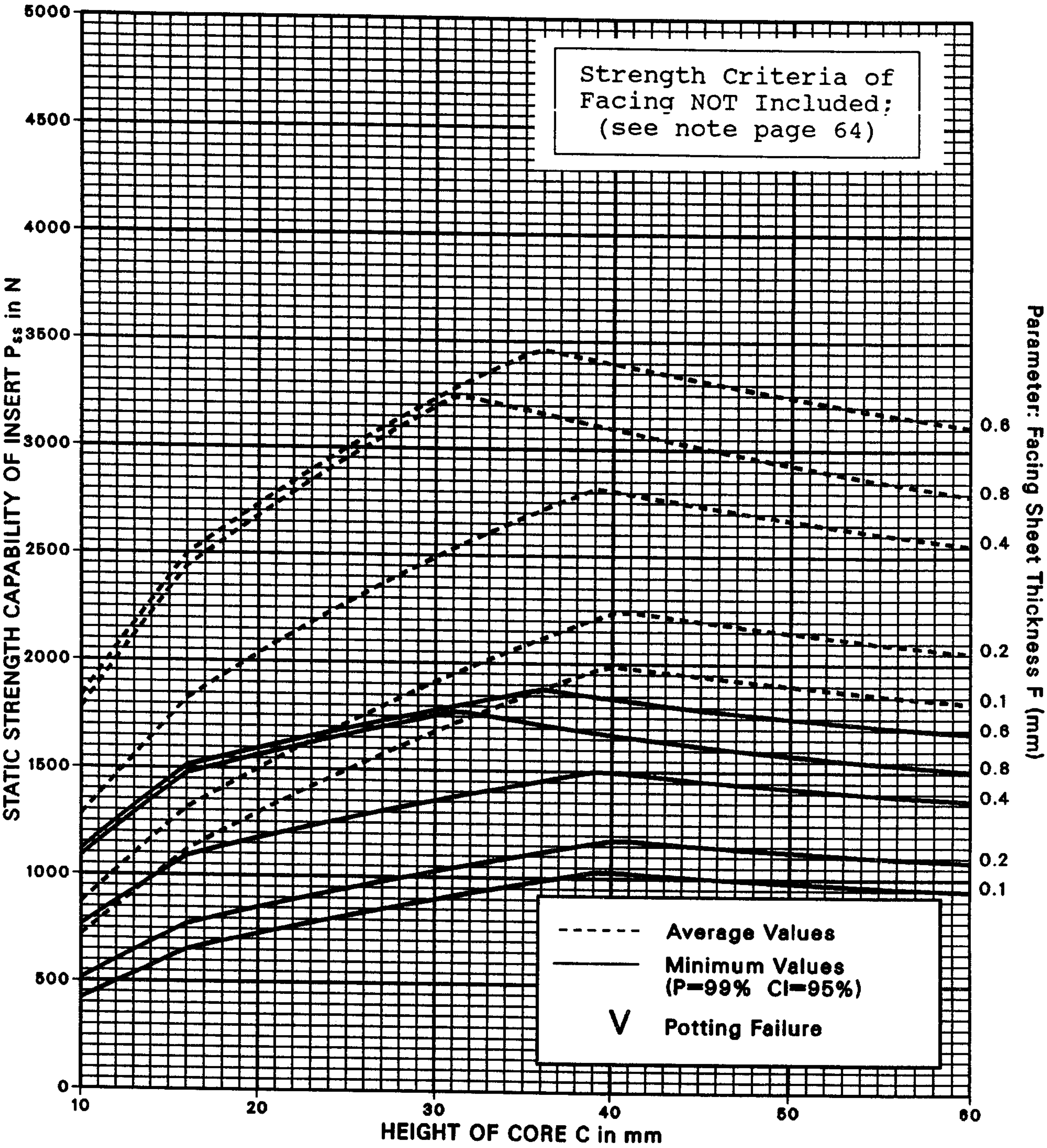


Insert Height h = 9 mm Facing Material AL 2024

Load : **Compression**

Insert Diameter: **14.0 mm**

Core : **HRH 10-3/16-3.0**



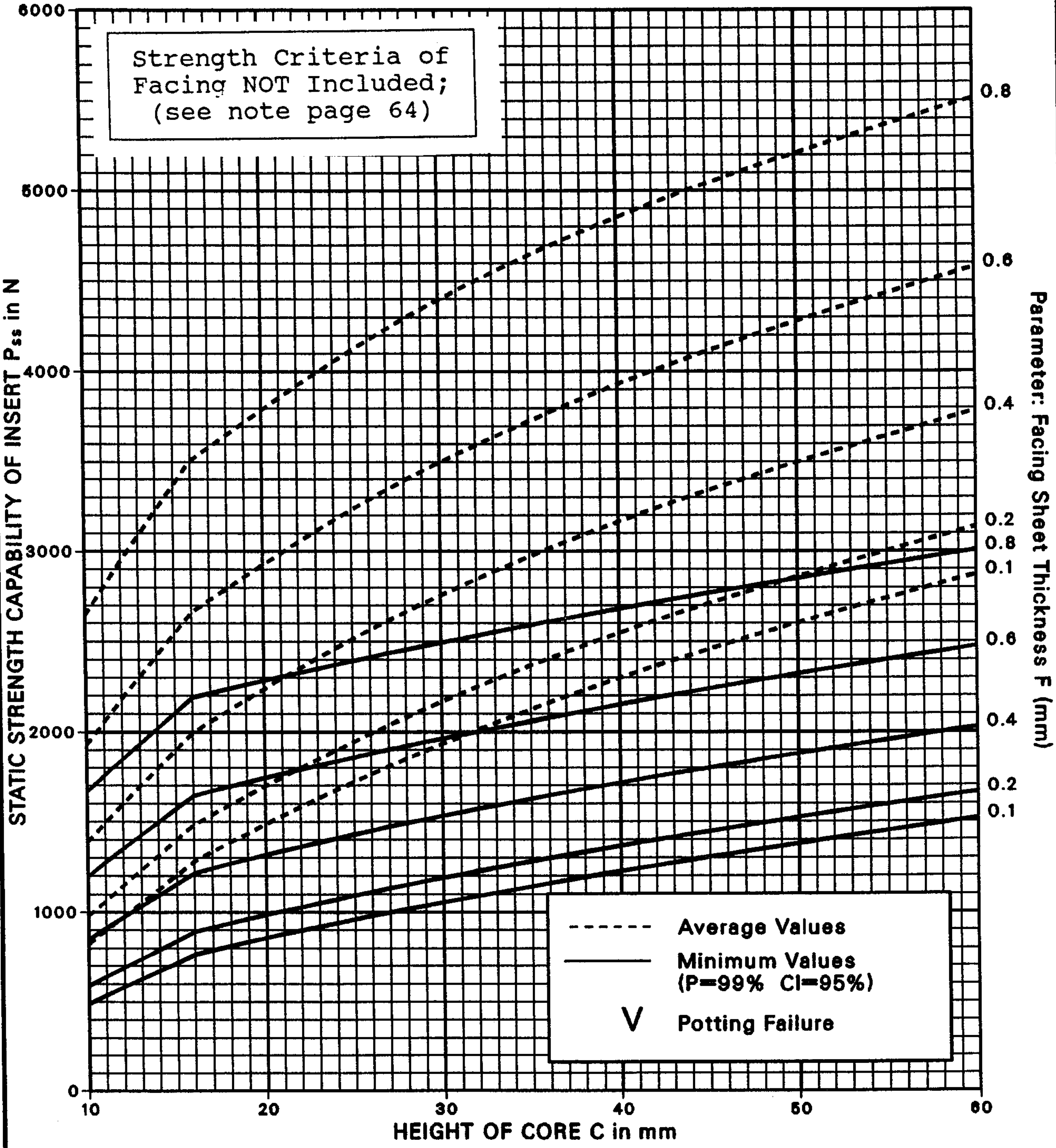
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **17.5 mm**

Core : **HRH 10-3/16-3.0**



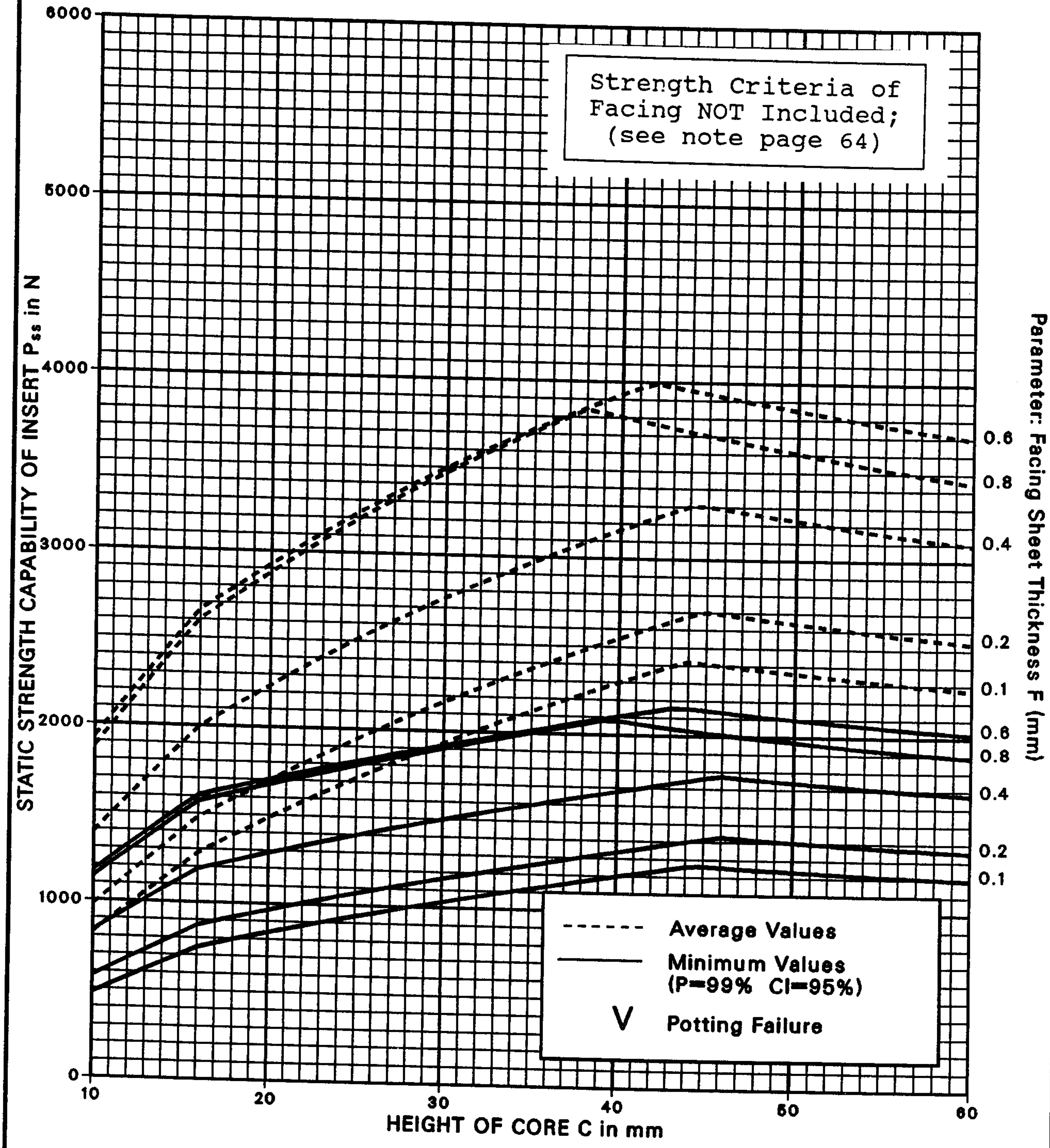
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Compression**

Insert Diameter: **17.5 mm**

Core : **HRH 10-3/16-3.0**

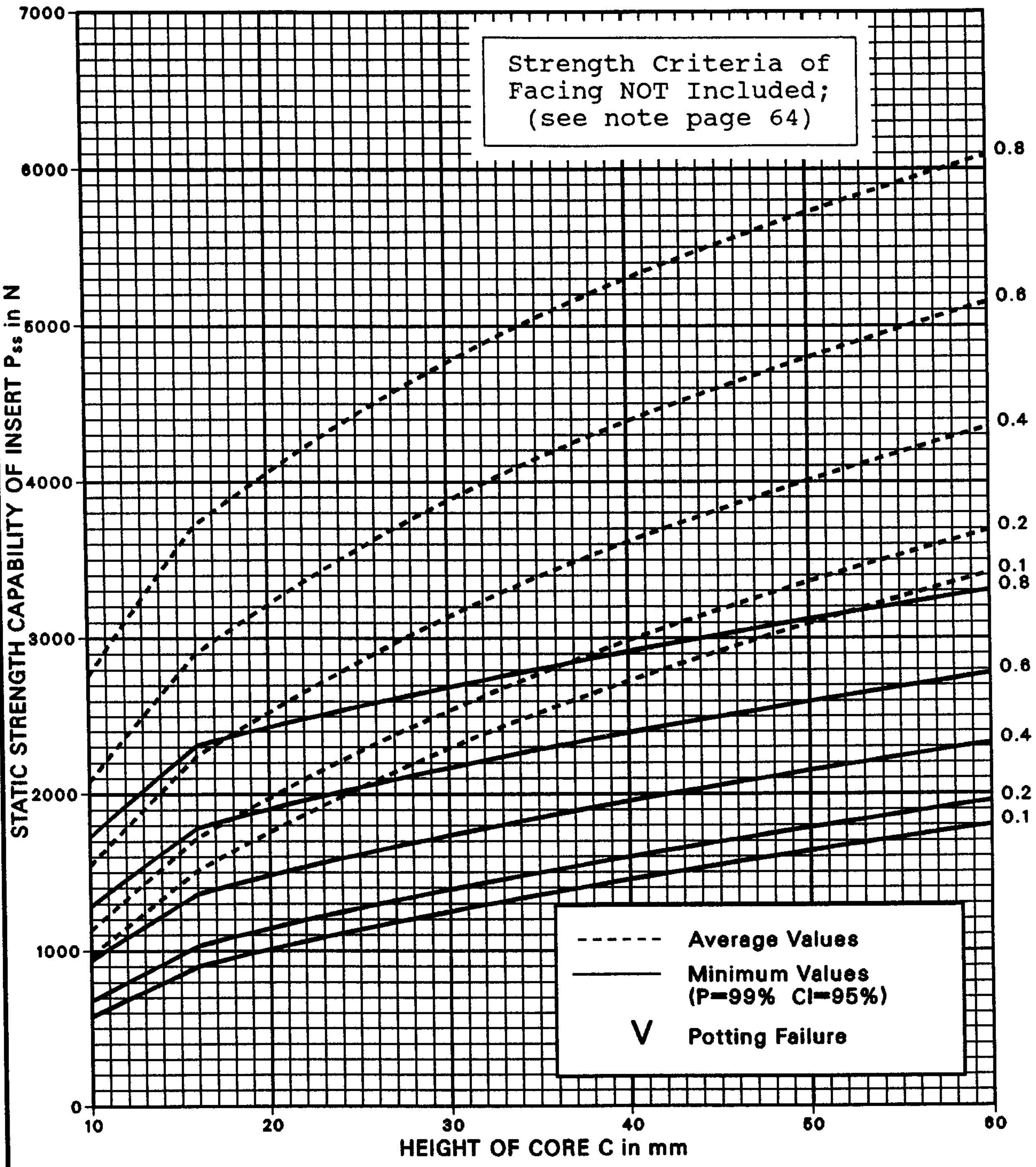


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Tension**

Insert Diameter: **22.5 mm**

Core : **HRH 10-3/16-3.0**

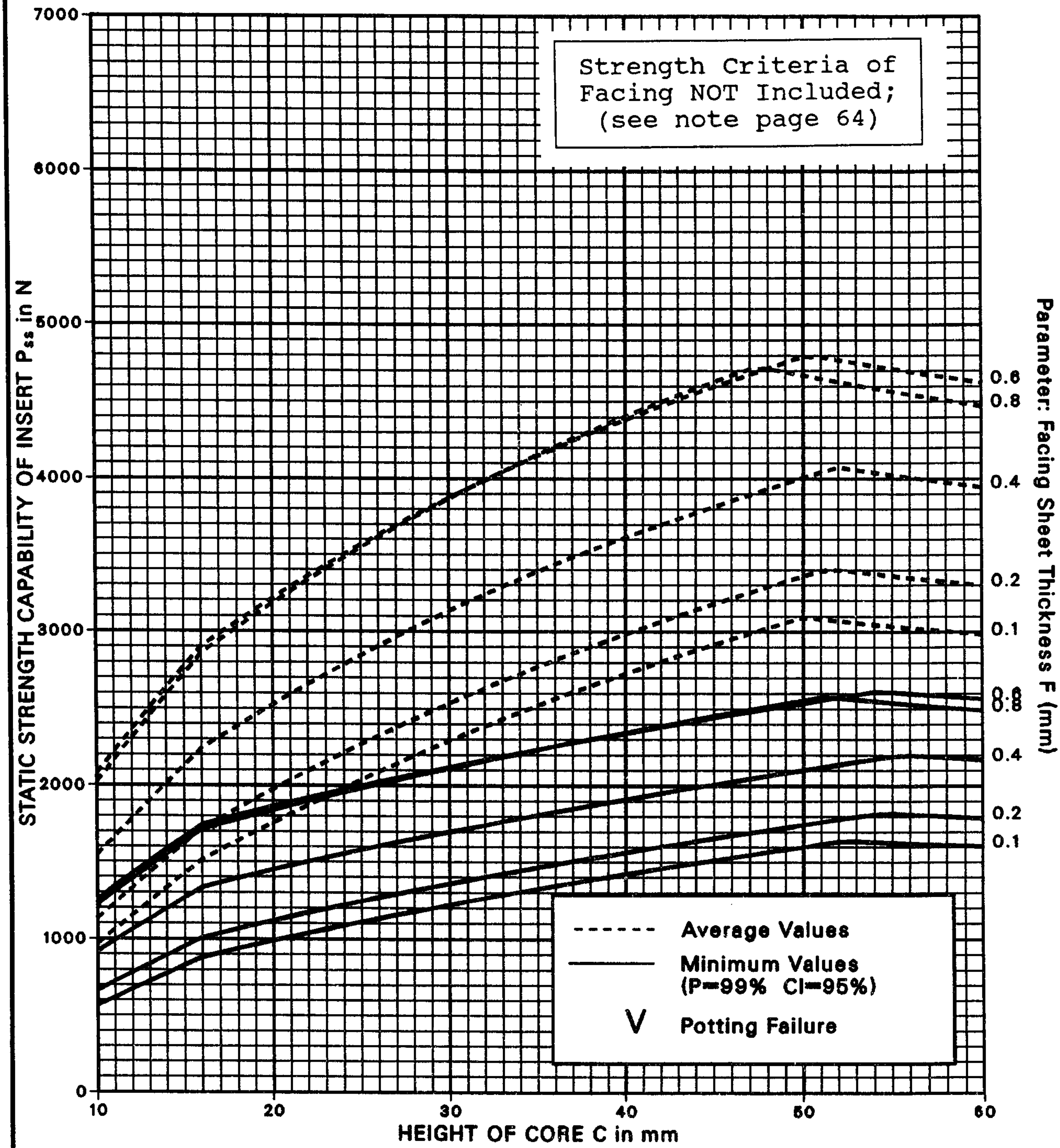


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Compression**

Insert Diameter: **22.5 mm**

Core : **HRH 10-3/16-3.0**



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11. HRH 10 – 3/16 – 4.0 Core

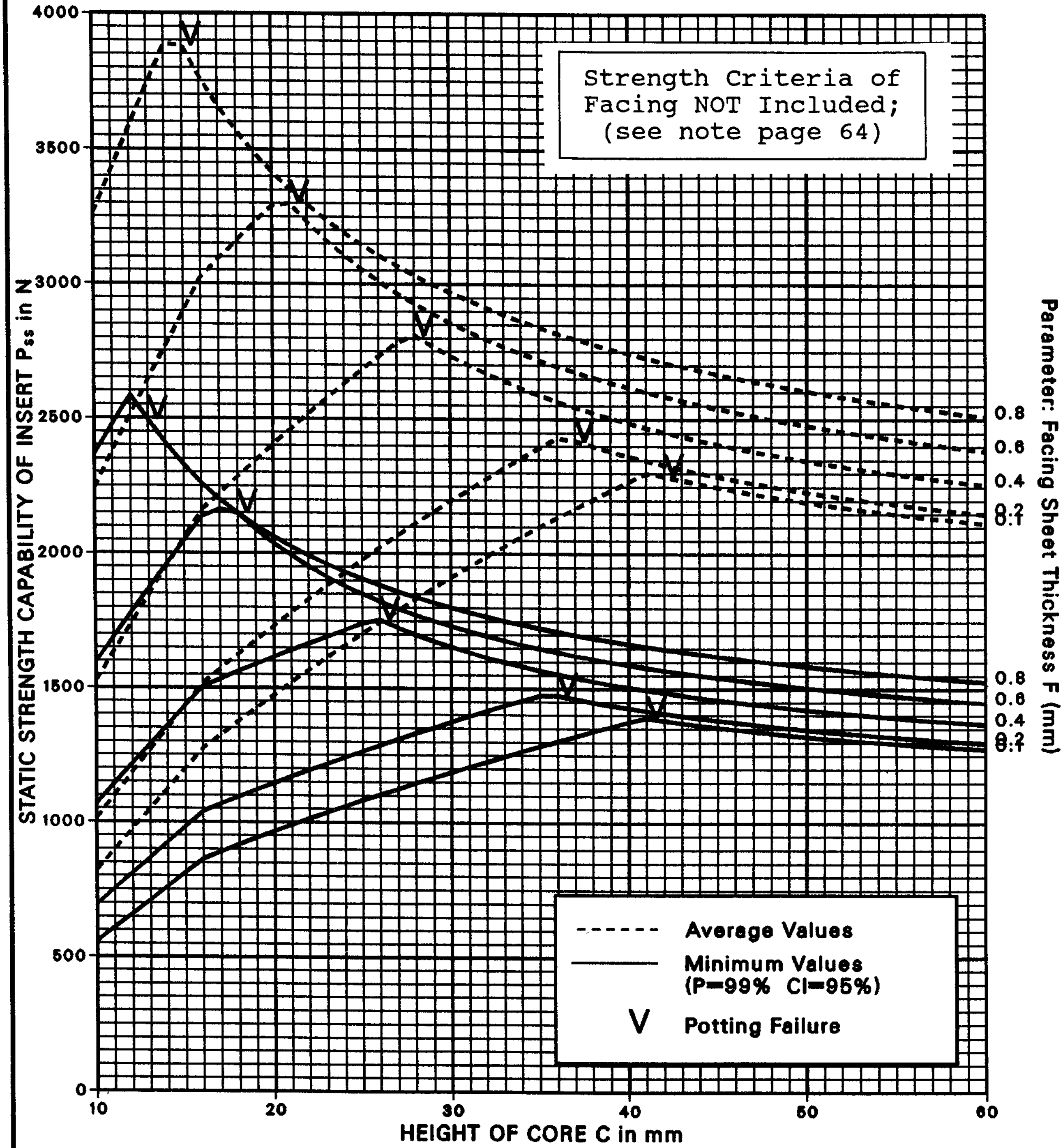
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **9.0 mm**

Core : **HRH 10-3/16-4.0**

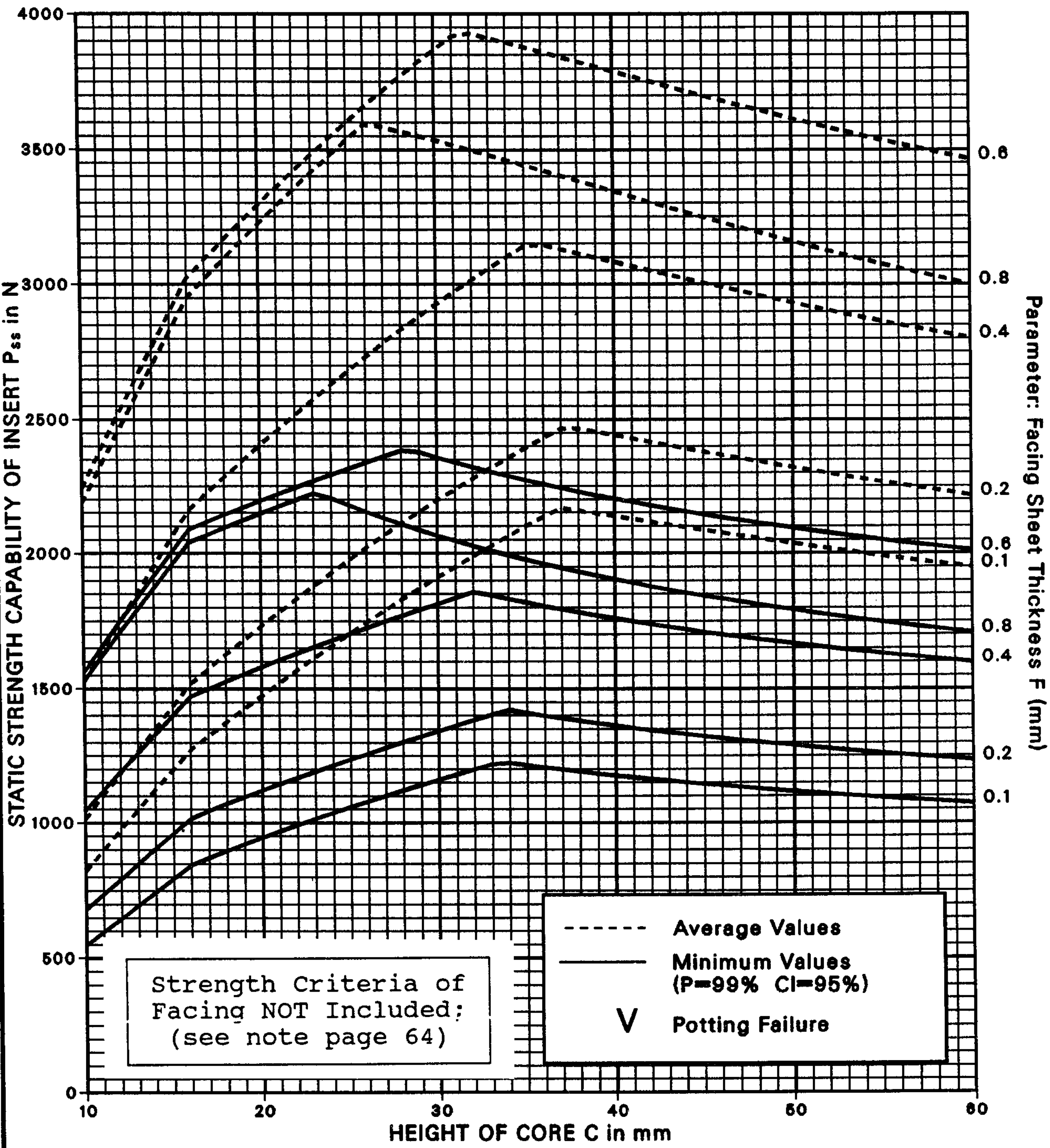


Insert Height h = 9 mm   Facing Material AL 2024

Load : Compression

Insert Diameter: 9.0 mm

Core : HRH 10-3/16-4.0

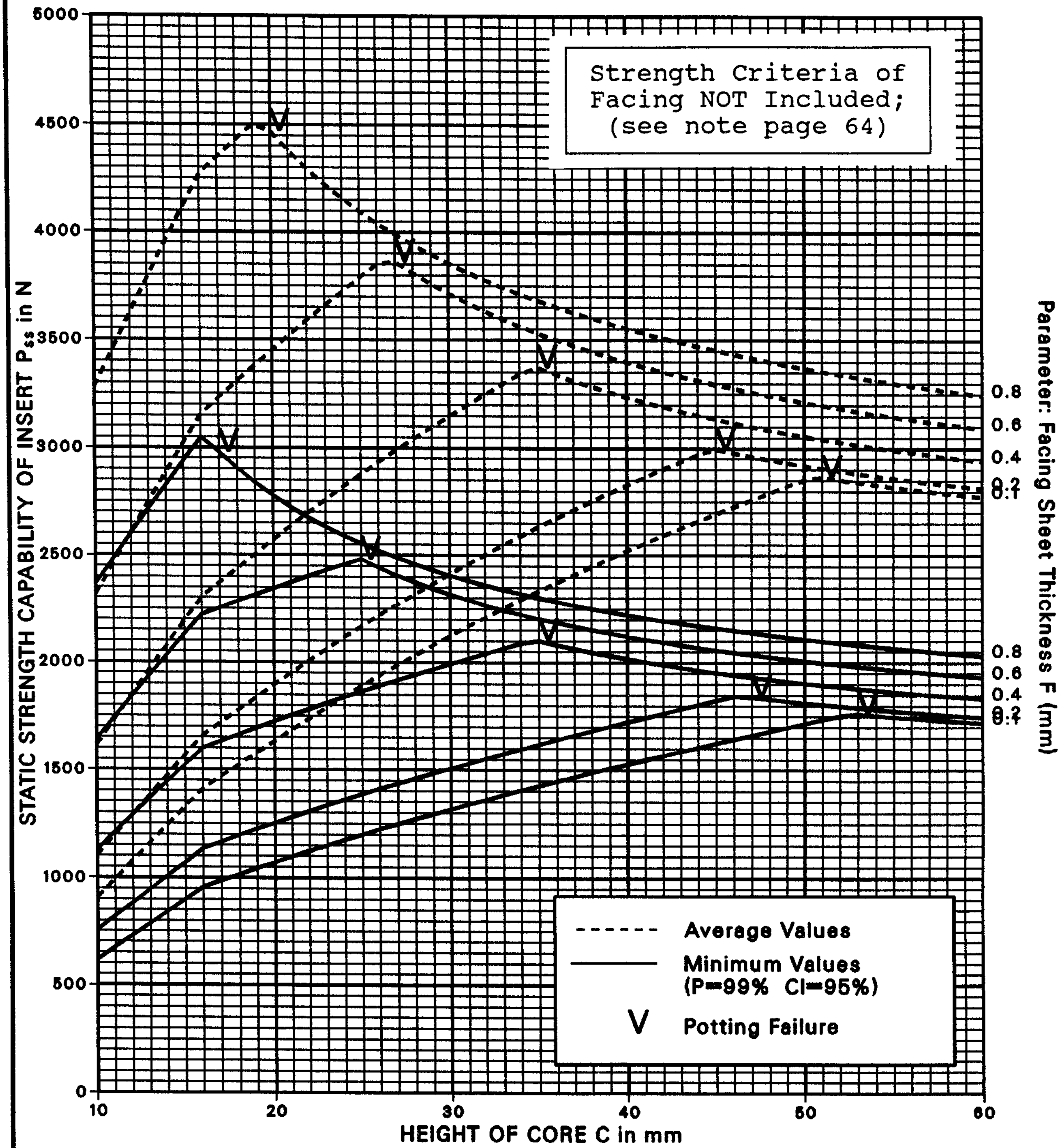


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **11.0 mm**

Core : **HRH 10-3/16-4.0**

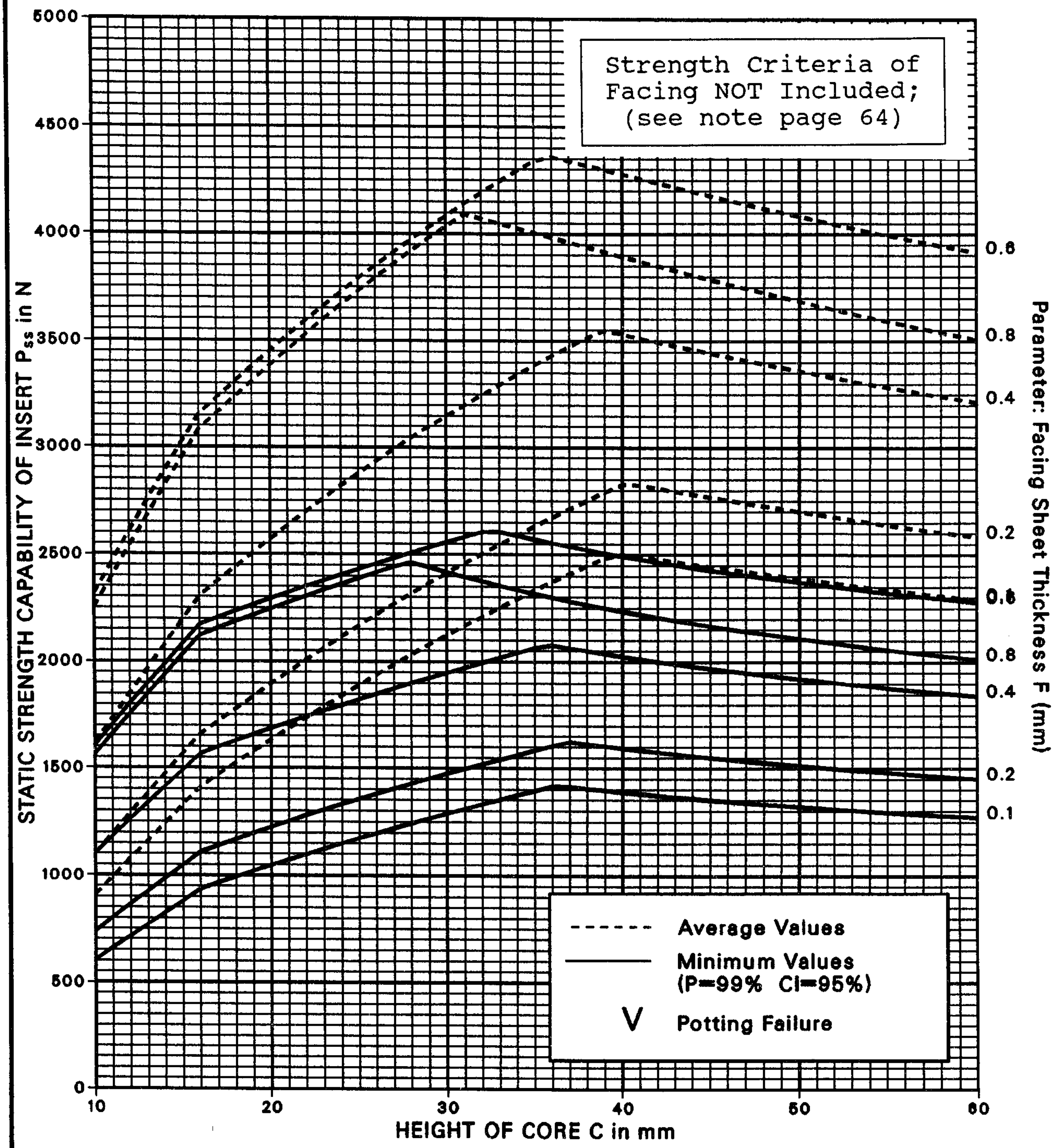


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 11.0 mm

Core : HRH 10-3/16-4.0

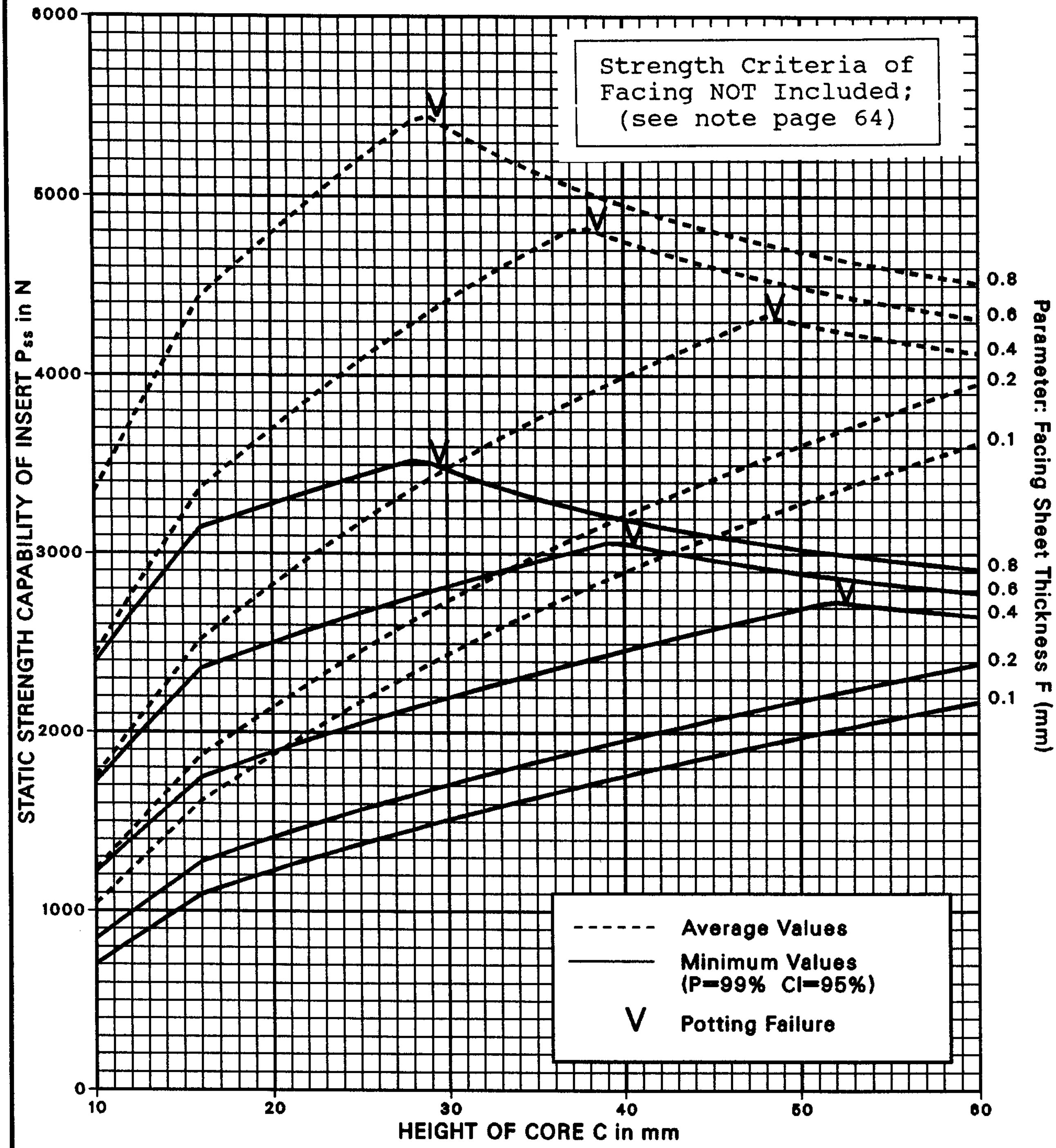


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **14.0 mm**

Core : **HRH 10-3/16-4.0**



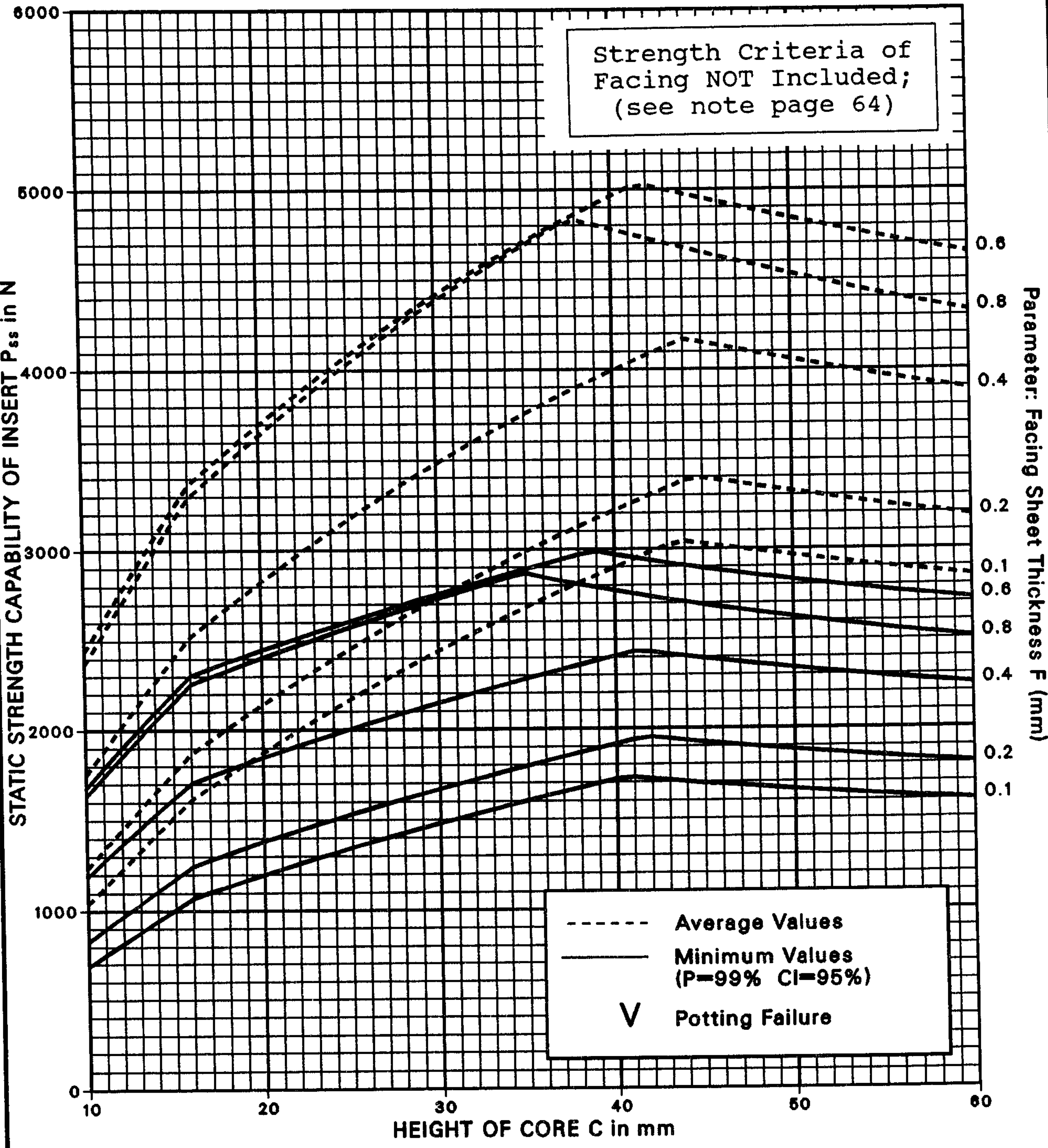
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Compression**

Insert Diameter: **14.0 mm**

Core : **HRH 10-3/16-4.0**

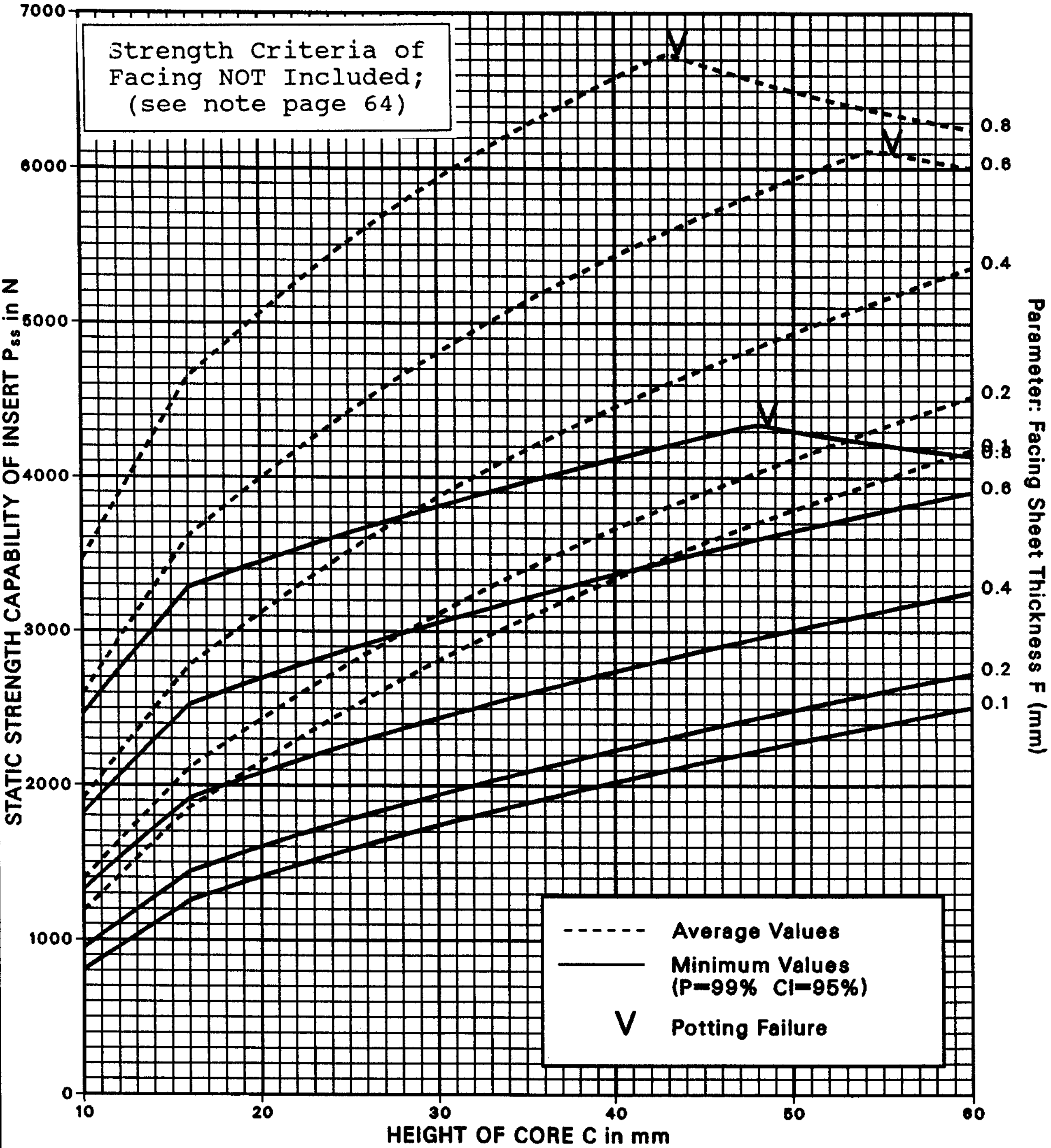


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Tension**

Insert Diameter: **17.5 mm**

Core : **HRH 10-3/16-4.0**

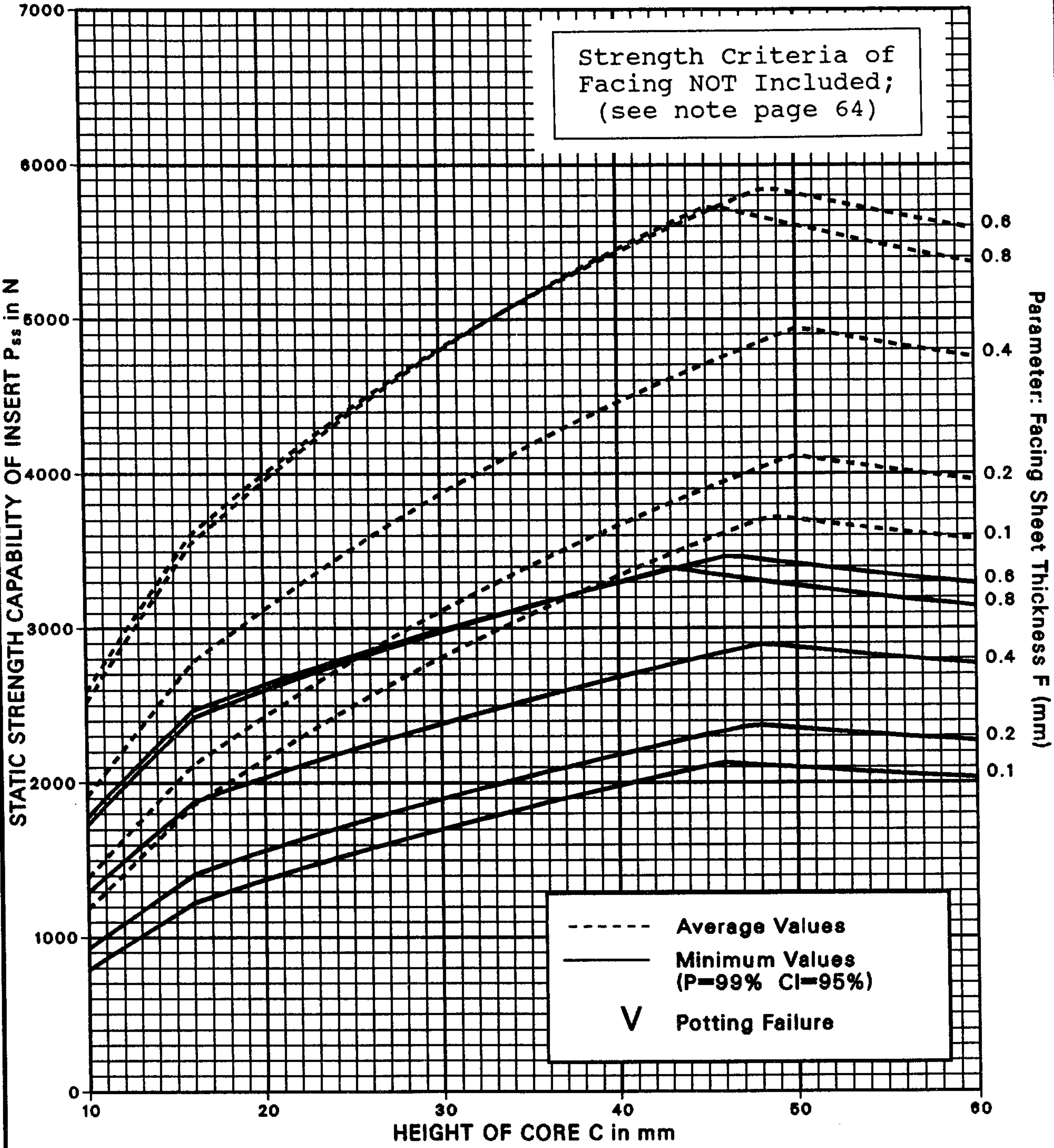


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Compression**

Insert Diameter: **17.5 mm**

Core : **HRH 10-3/16-4.0**

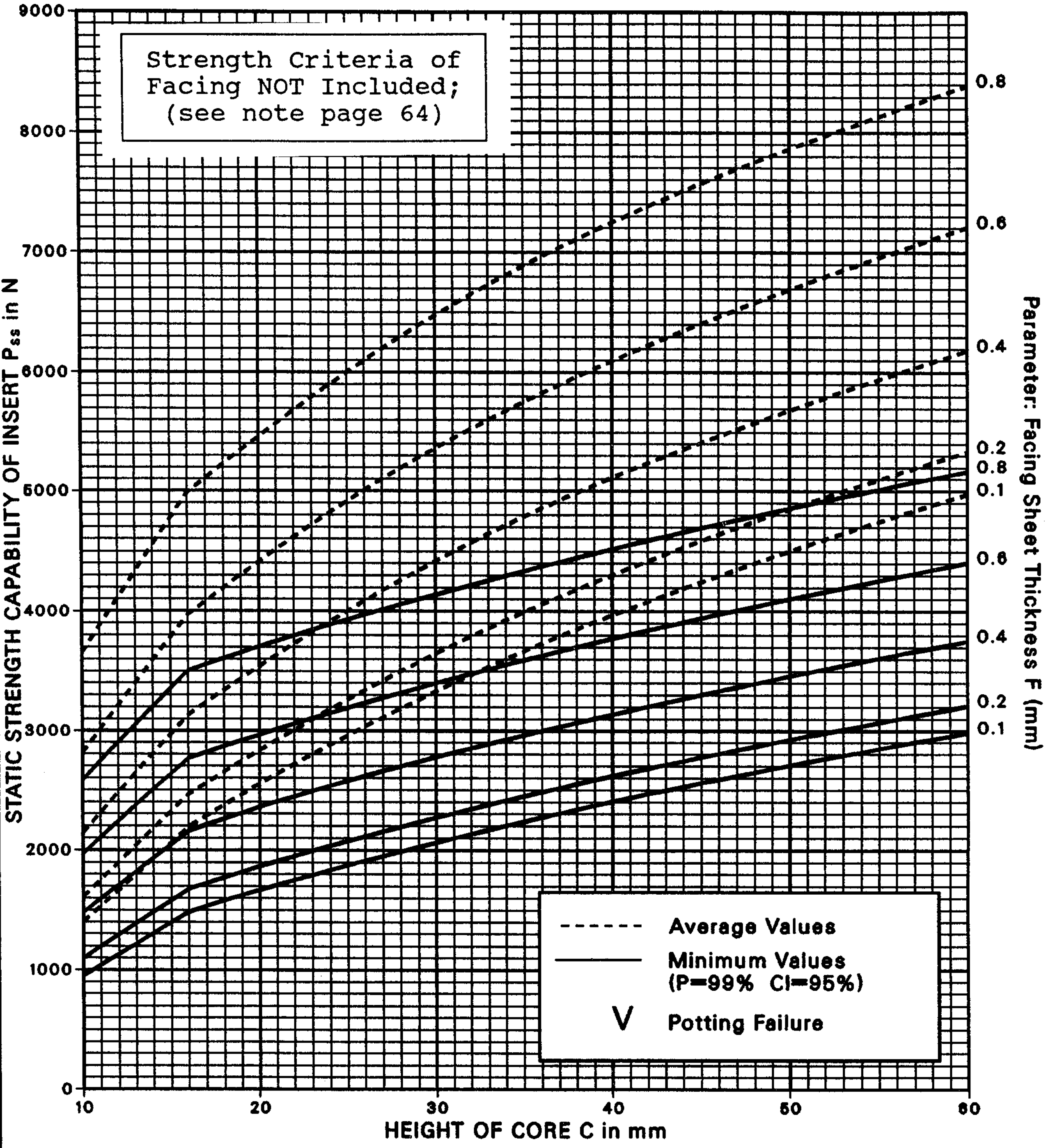


Insert Height h = 9 mm | Facing Material AL 2024

Load : Tension

Insert Diameter: 22.5 mm

Core : HRH 10-3/16-4.0

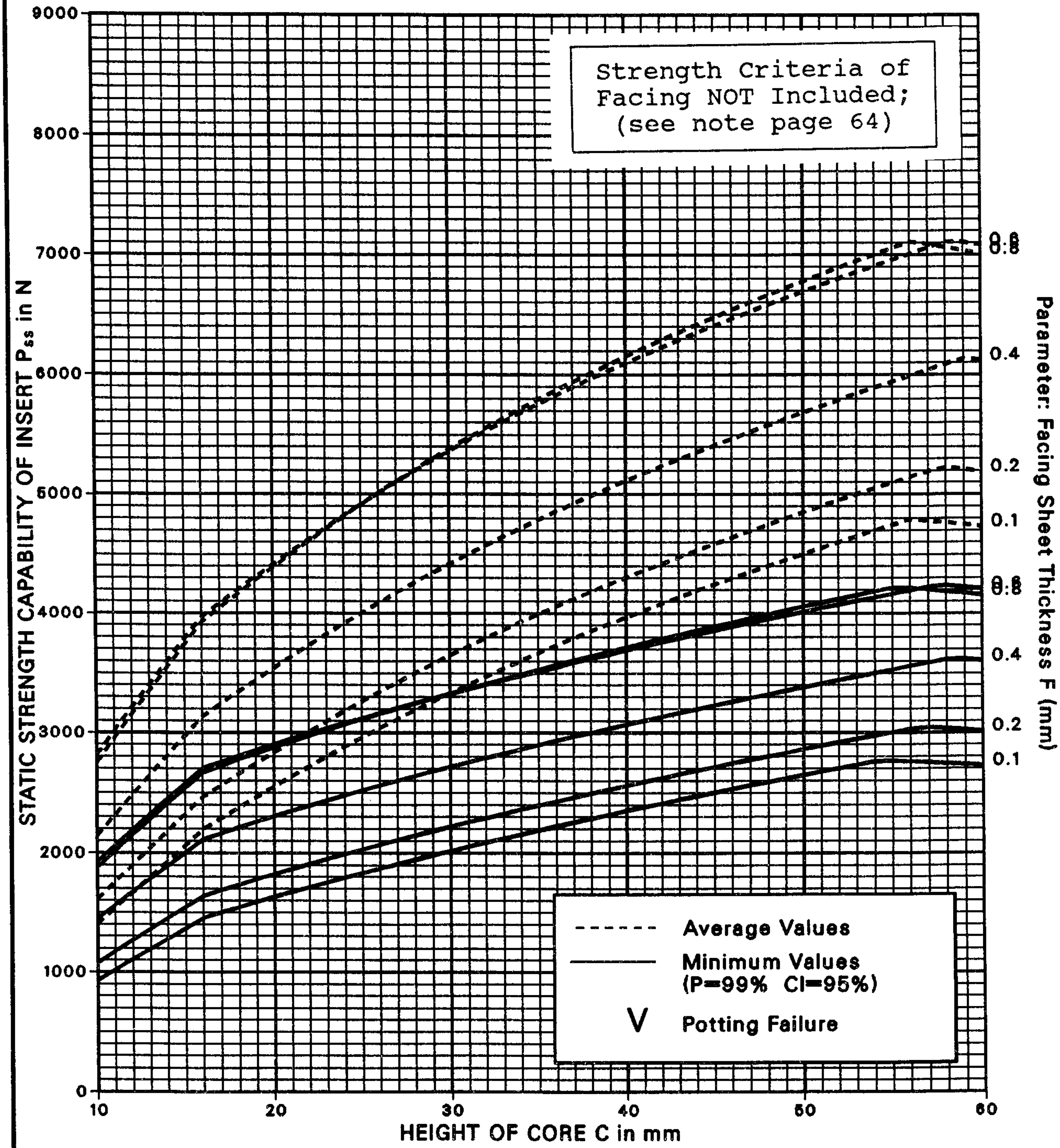


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Compression**

Insert Diameter: **22.5 mm**

Core : **HRH 10-3/16-4.0**



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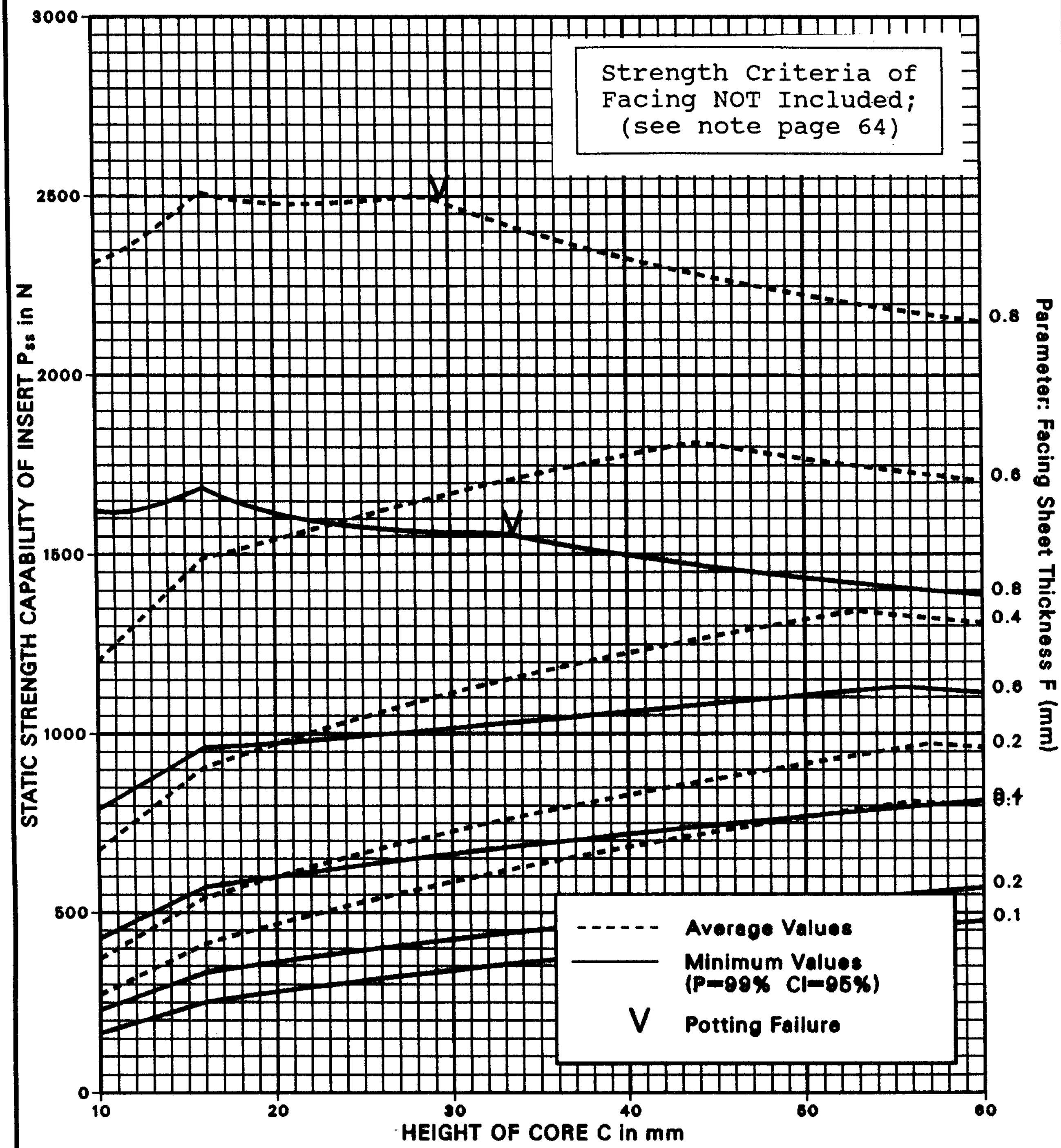
12. HRH 10 – 1/8 – 1.8 Core

Insert Height h = 9 mm	Facing Material AL 2024

Load : **Tension**

Insert Diameter: **9.0 mm**

Core : **HRH 10-1/8-1.8**

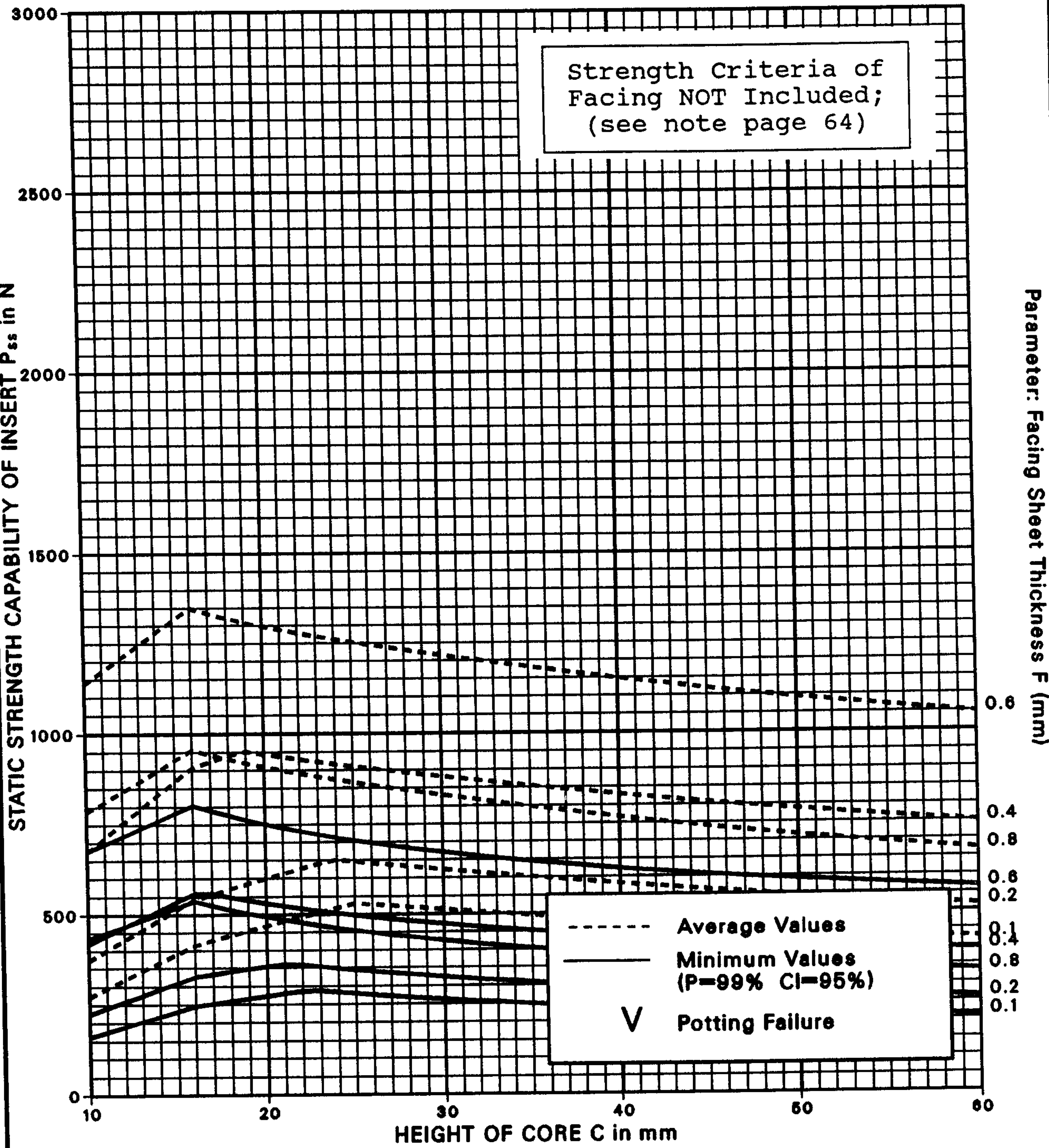


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 9.0 mm

Core : HRH 10-1/8-1.8

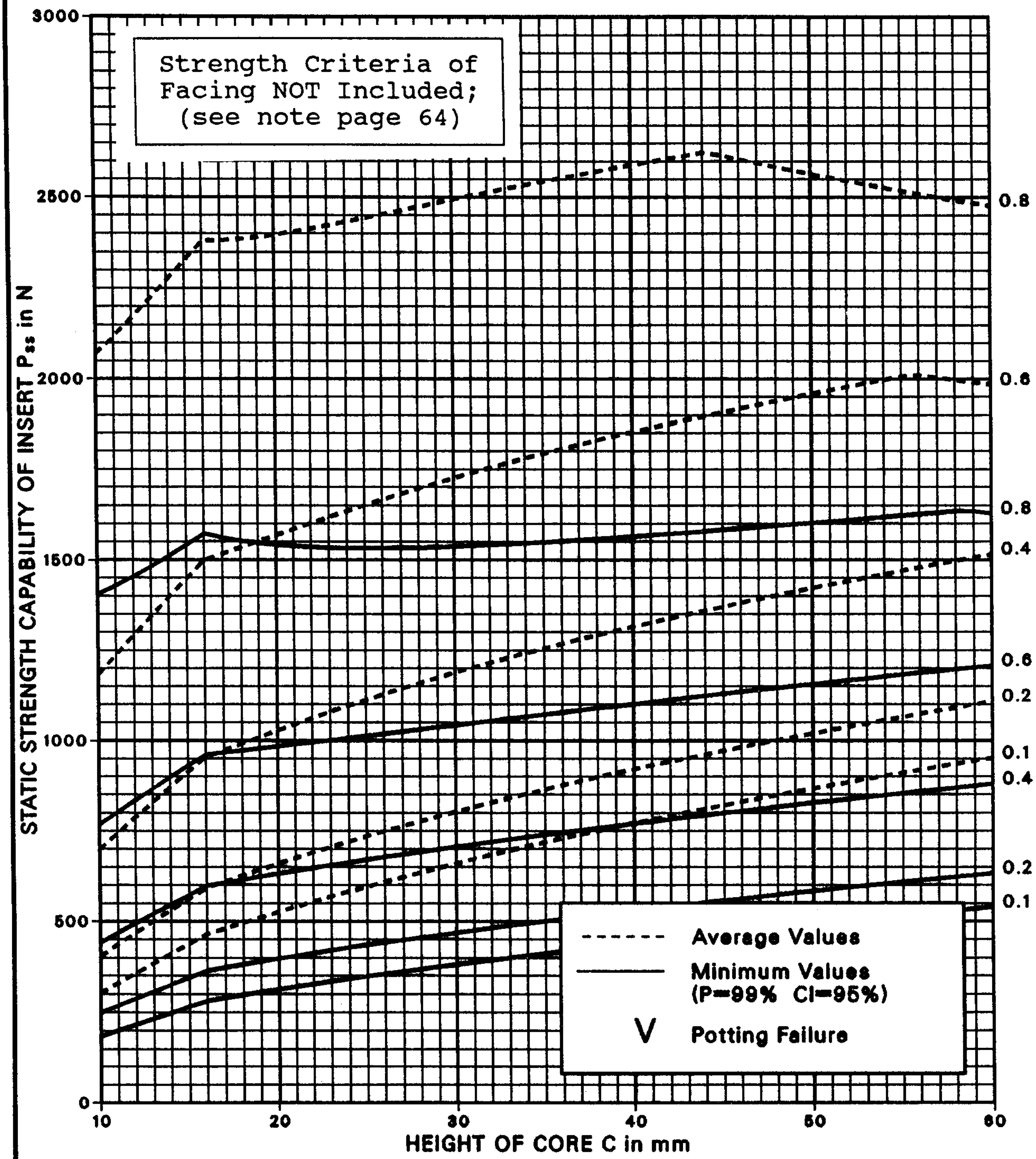


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **11.0 mm**

Core : **HRH 10-1/8-1.8**

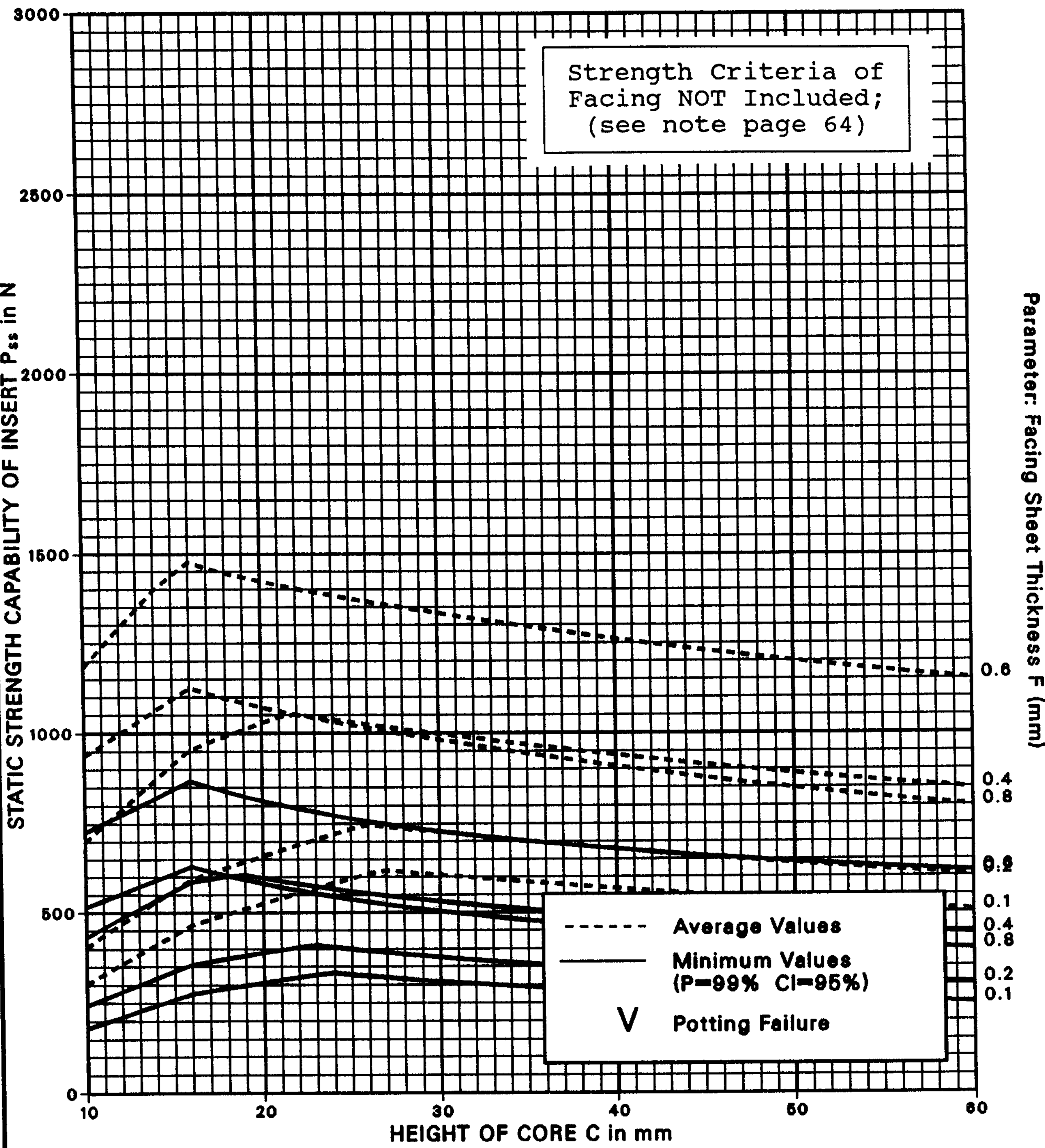


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Compression**

Insert Diameter: **11.0 mm**

Core : **HRH 10-1/8-1.8**

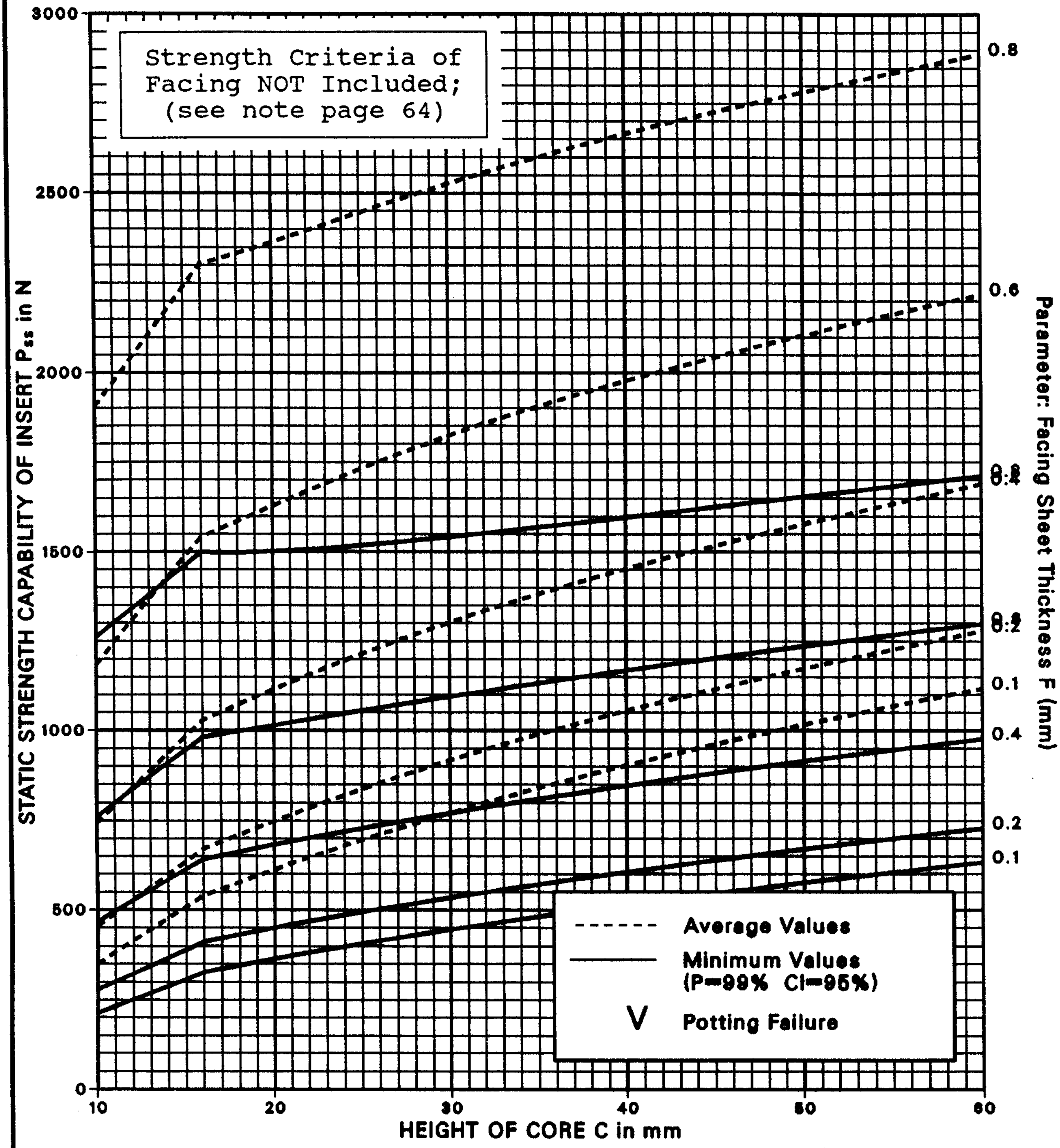


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Tension**

Insert Diameter: **14.0 mm**

Core : **HRH 10-1/8-1.8**

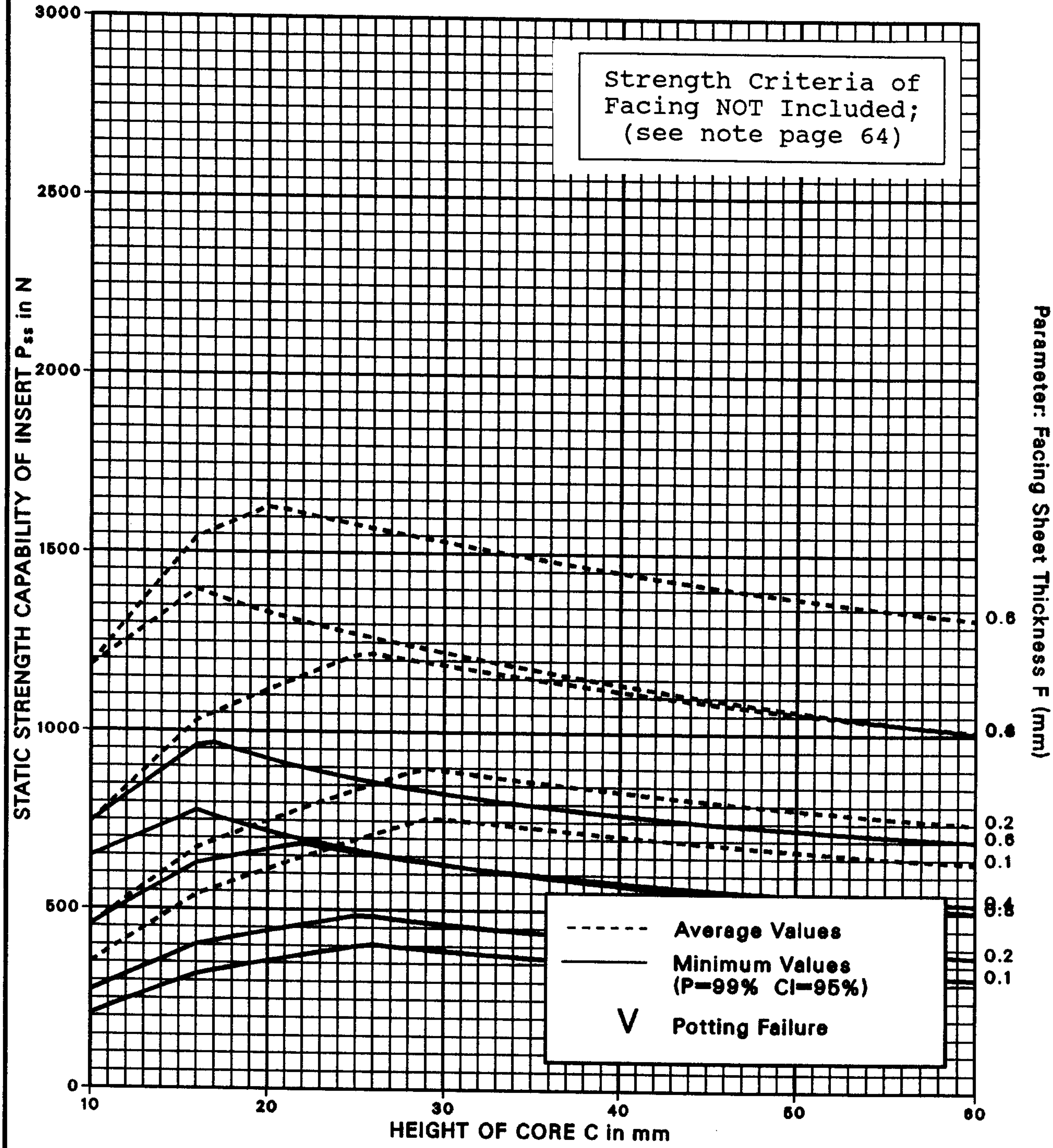


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 14.0 mm

Core : HRH 10-1/8-1.8

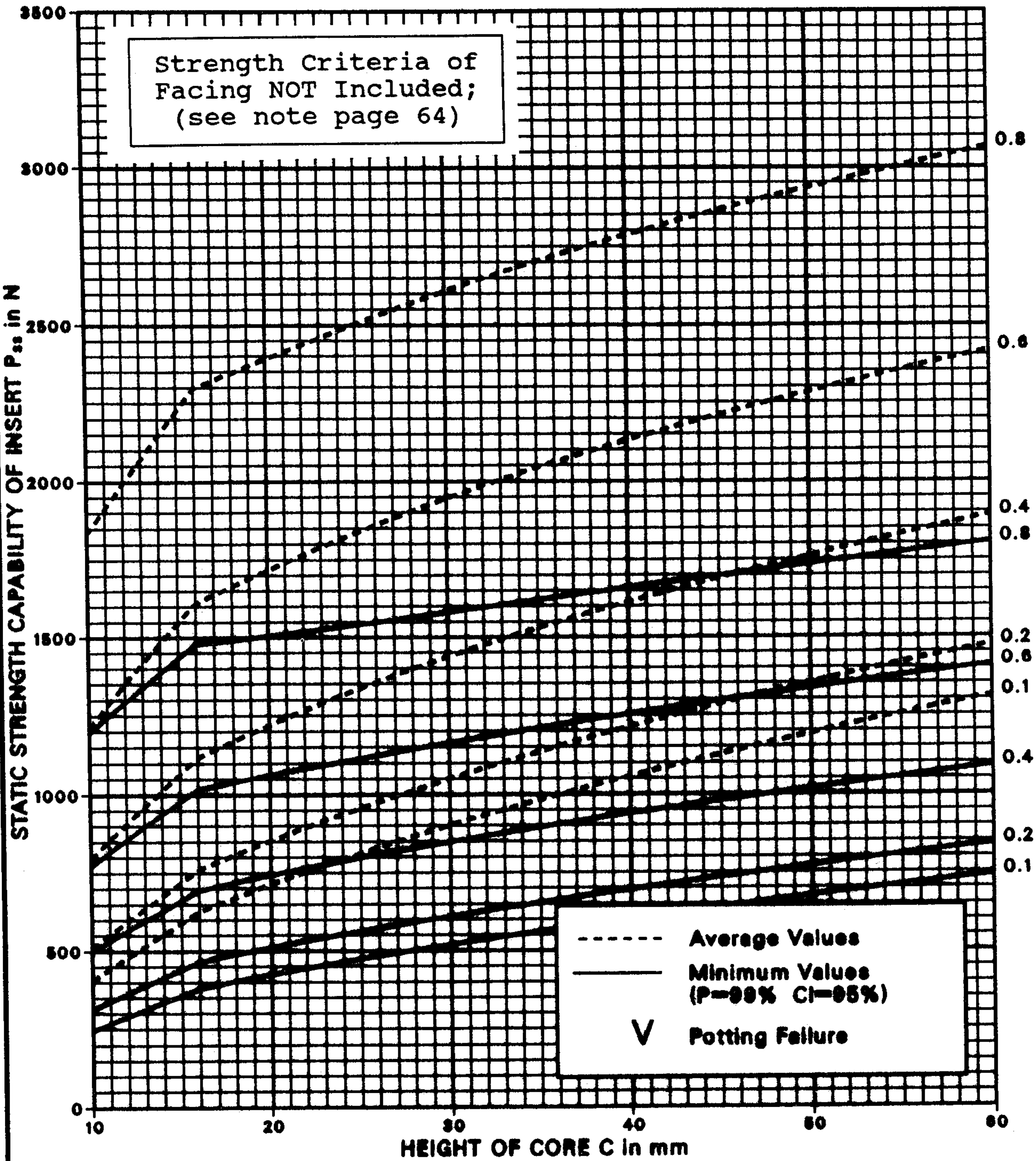


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Tension**

Insert Diameter: **17.5 mm**

Core : **HRH 10-1/8-1.8**

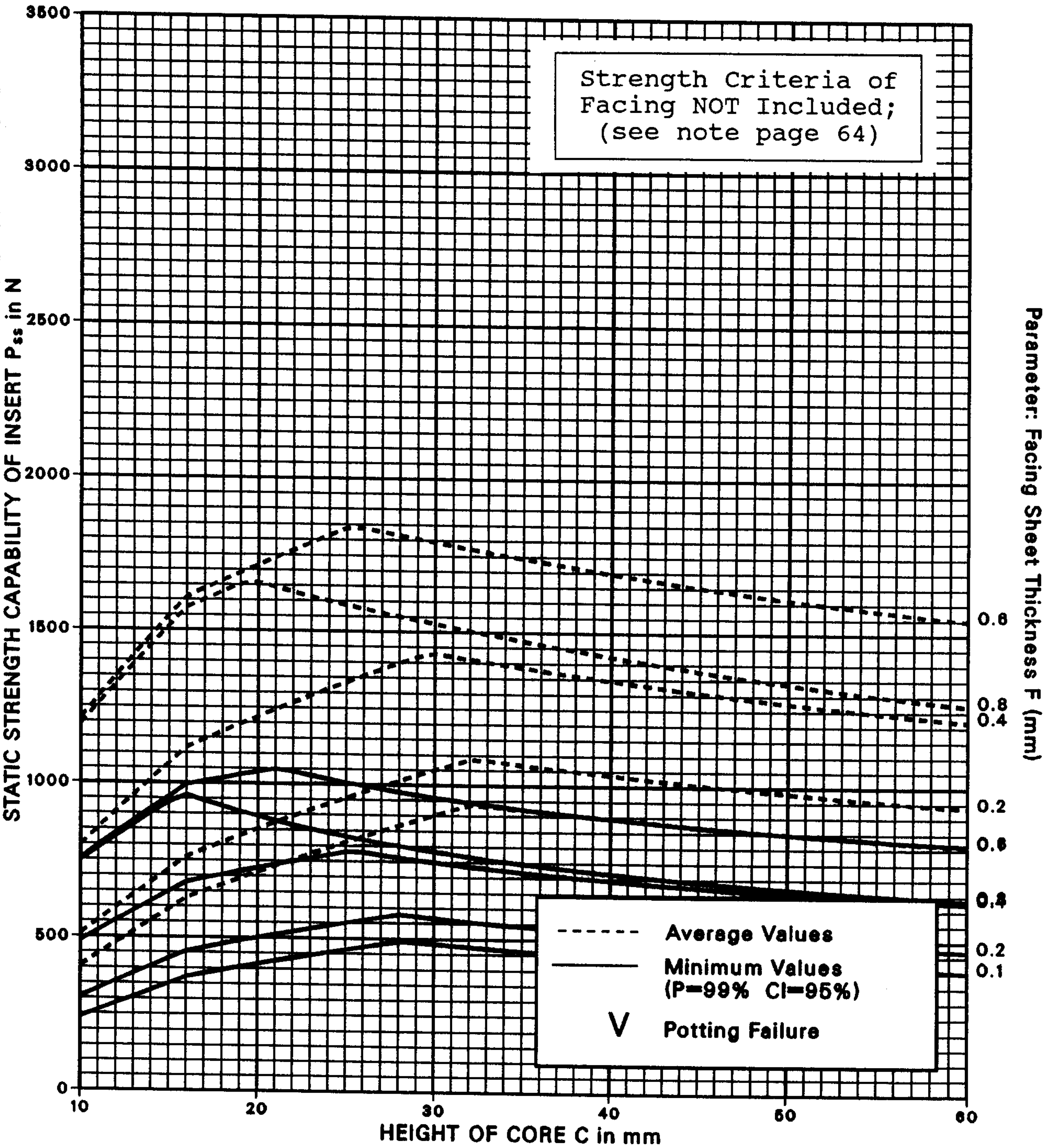


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Compression**

Insert Diameter: **17.5 mm**

Core : **HRH 10-1/8-1.8**

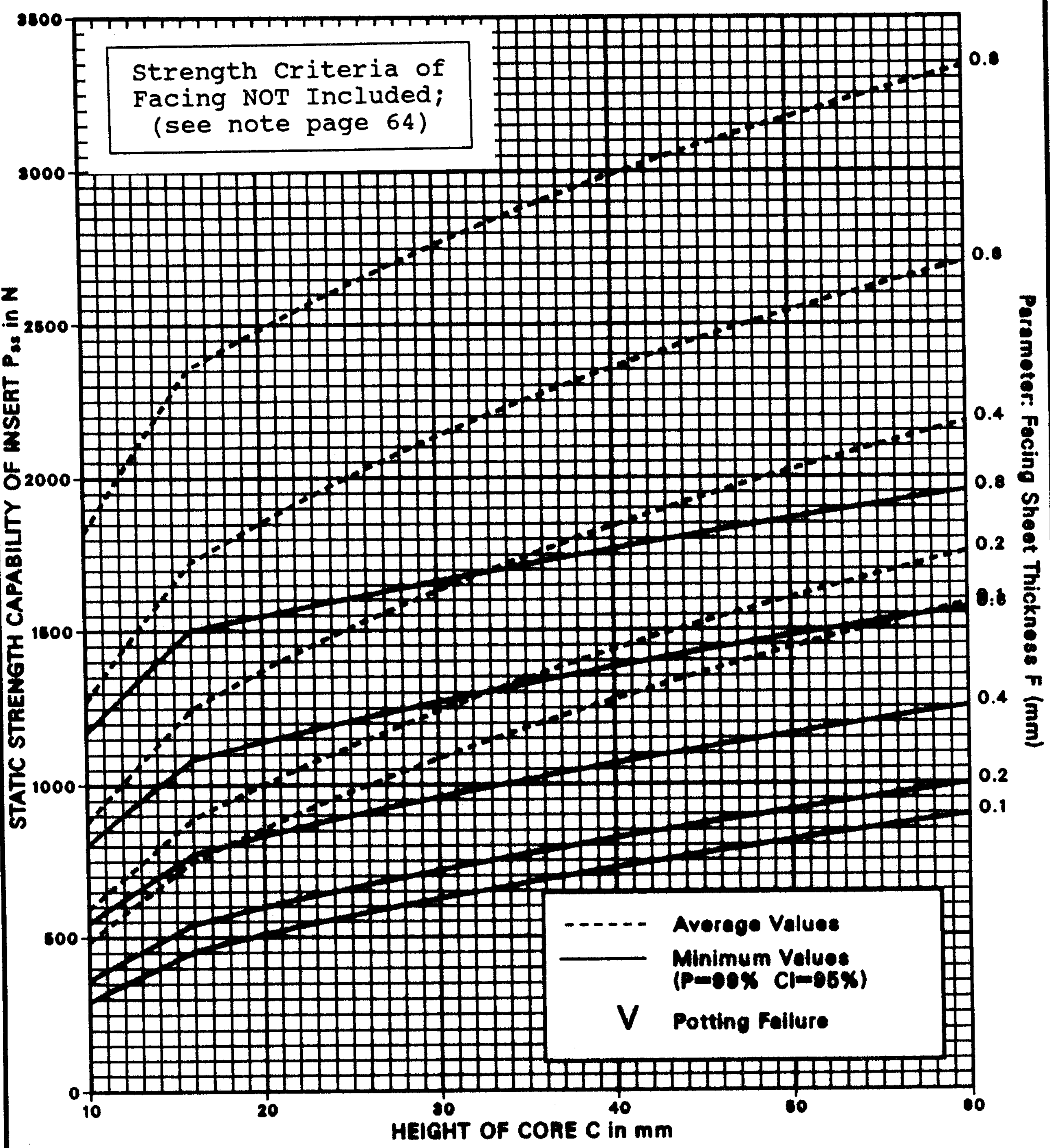


Insert Height h = 9 mm | Facing Material AL 2024

Load : Tension

Insert Diameter: 22.5 mm

Core : HRH 10-1/8-1.8



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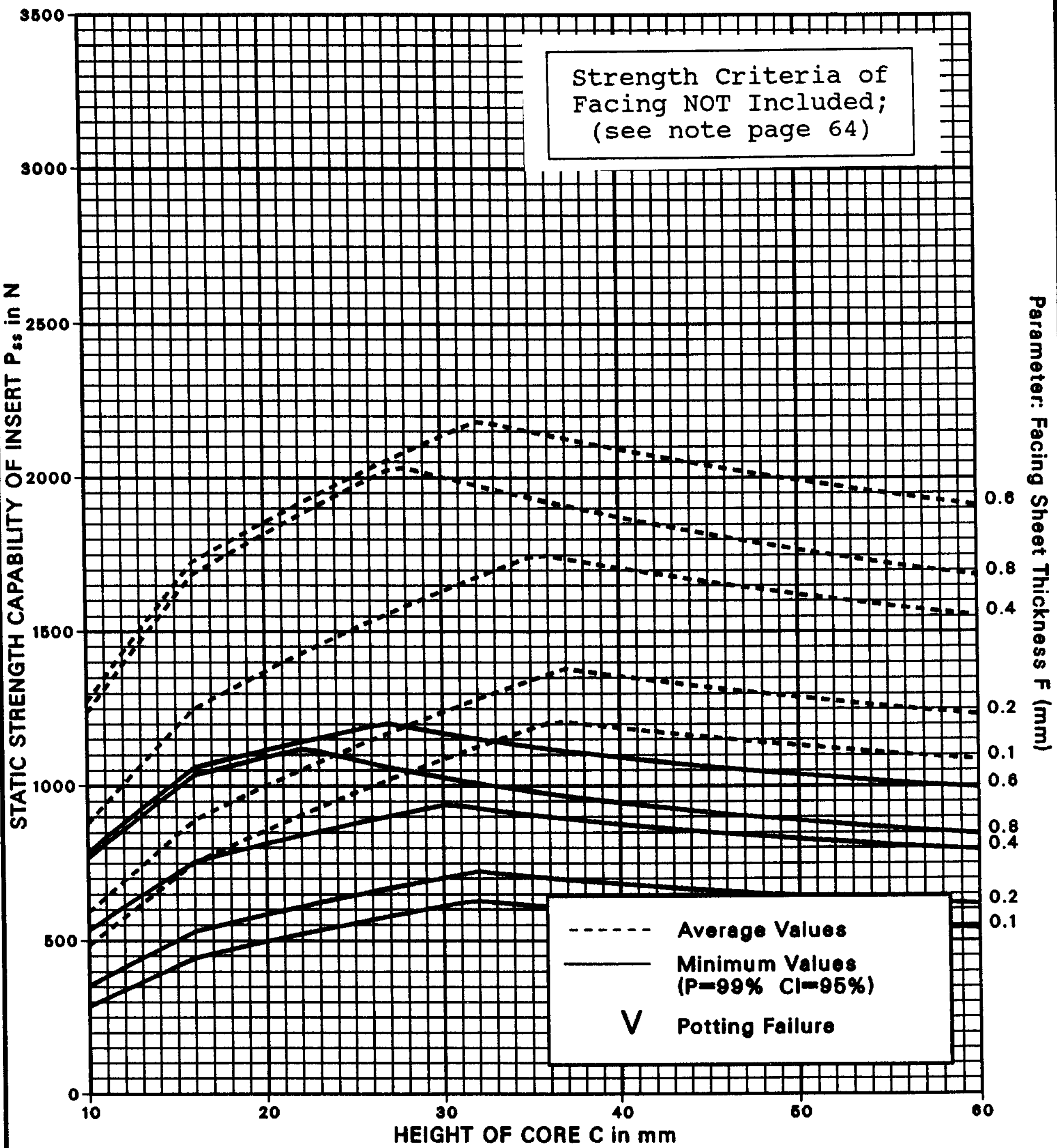
Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 22.5 mm

Core : HRH 10-1/8-1.8



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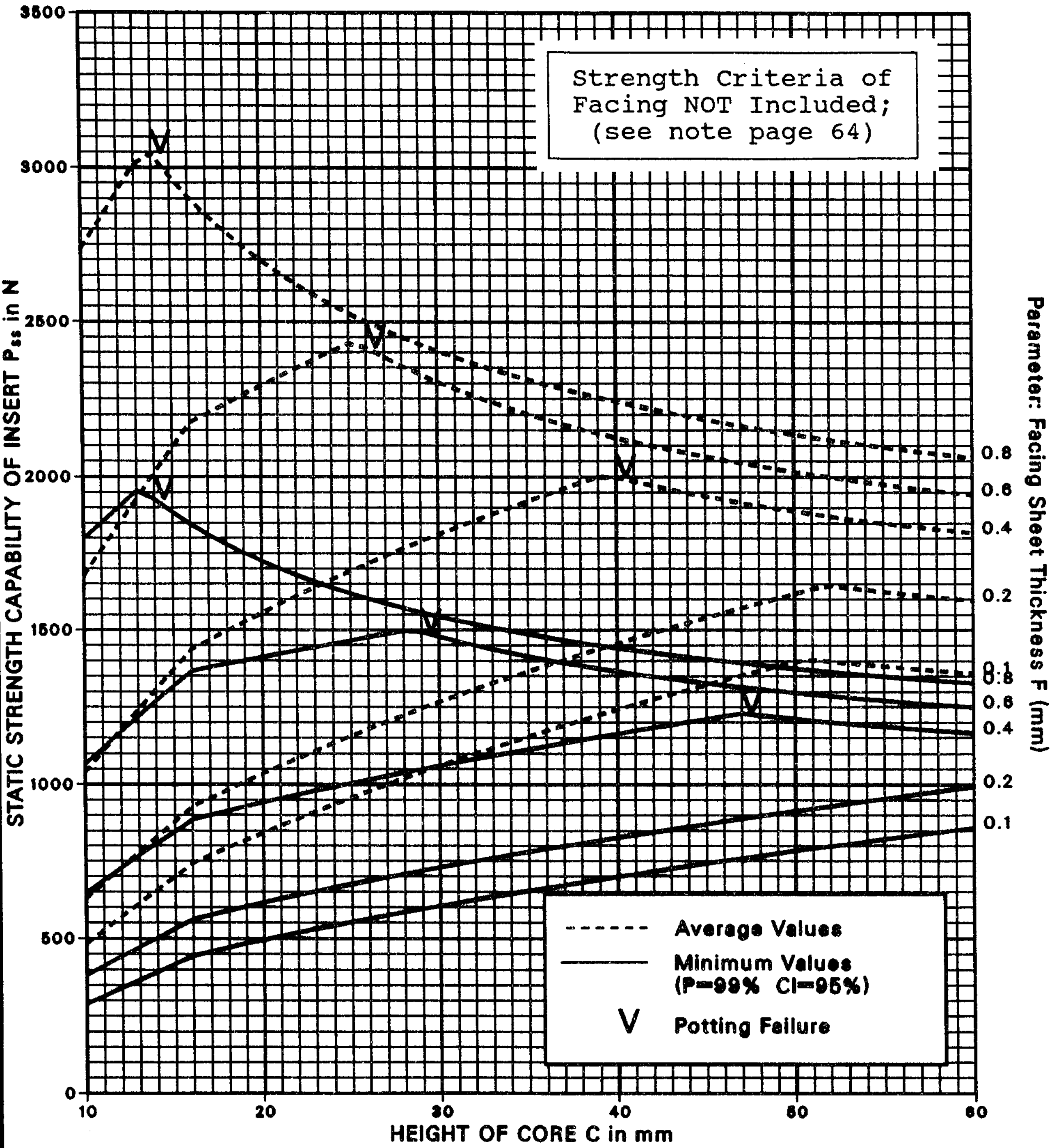
13. HRH 10 – 1/8 – 3.0 Core

Insert Height h = 9 mm | Facing Material AL 2024

Load : Tension

Insert Diameter: 9.0 mm

Core : HRH 10-1/8-3.0

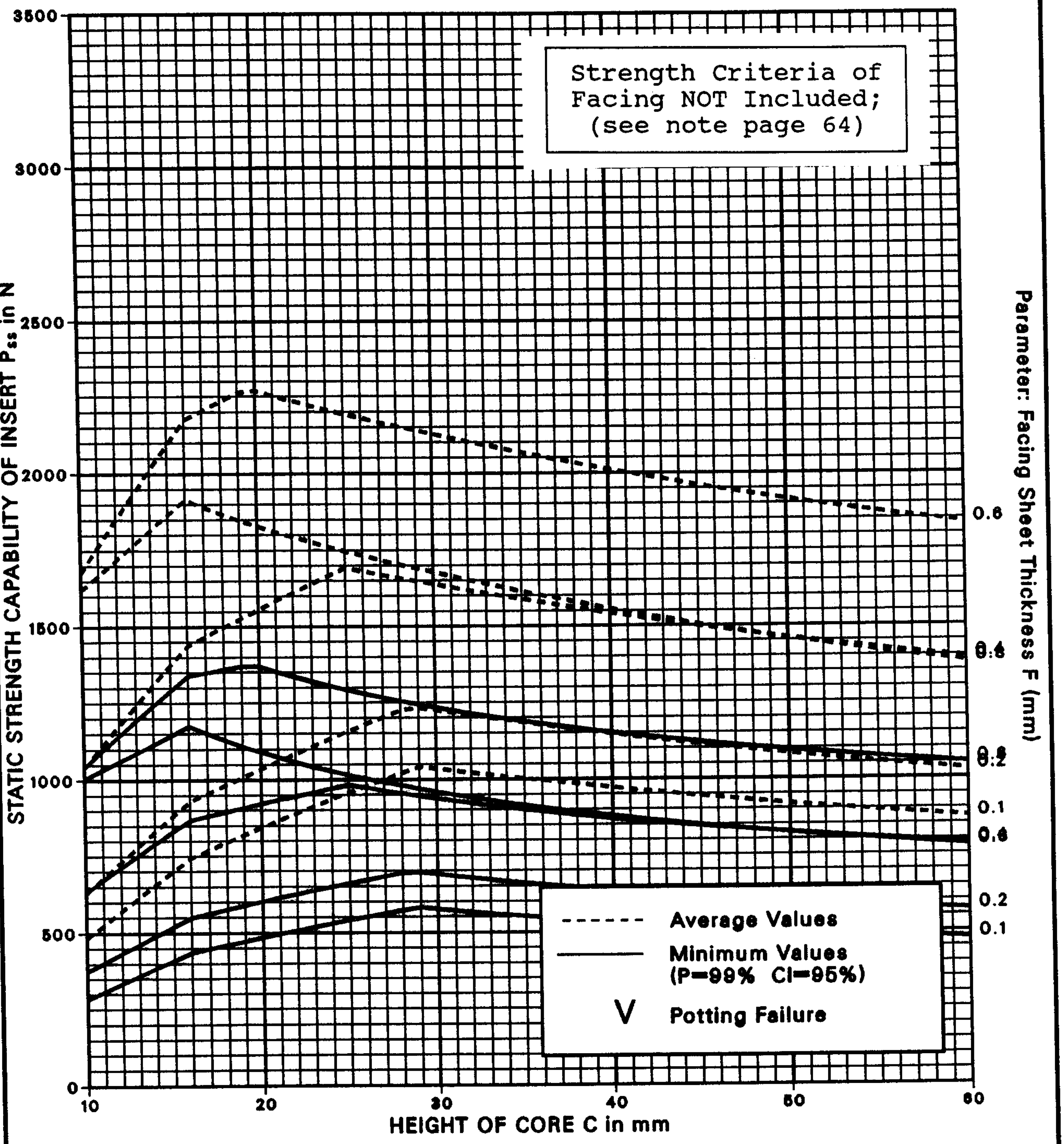


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 9.0 mm

Core : HRH 10-1/8-3.0

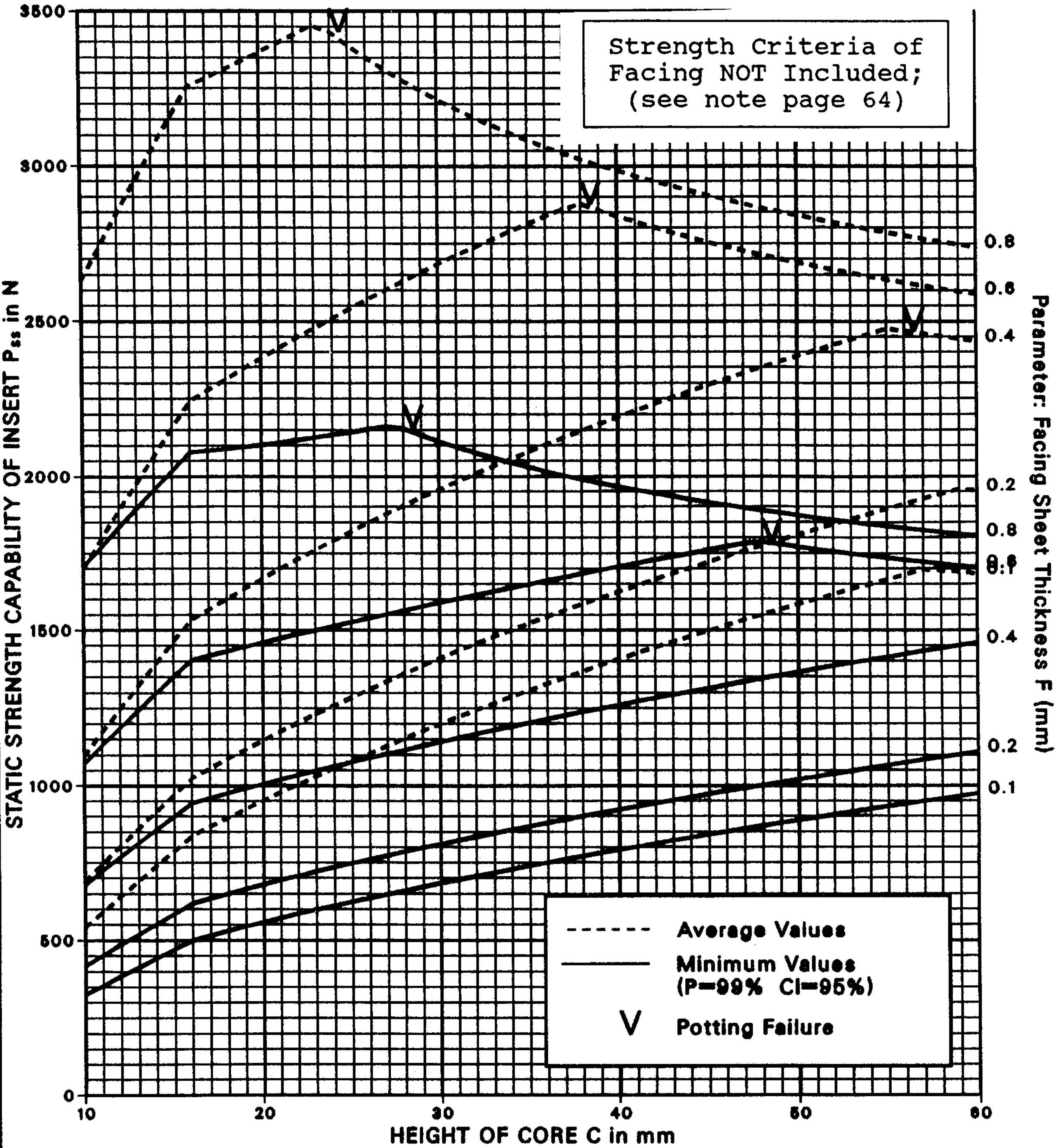


Insert Height h = 9 mm | Facing Material AL 2024

Load : Tension

Insert Diameter: 11.0 mm

Core : HRH 10-1/8-3.0

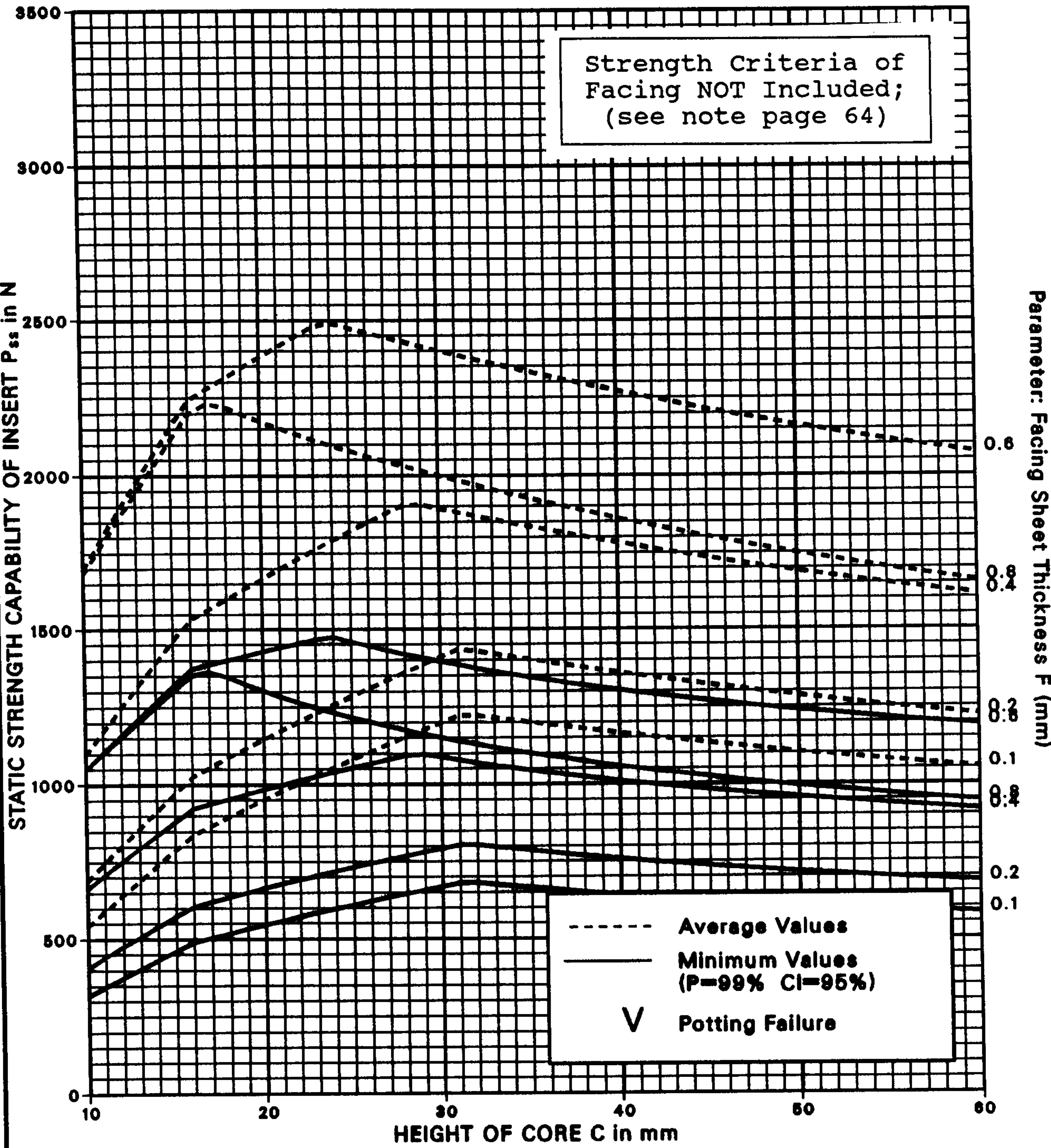


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Compression**

Insert Diameter: **11.0 mm**

Core : **HRH 10-1/8-3.0**

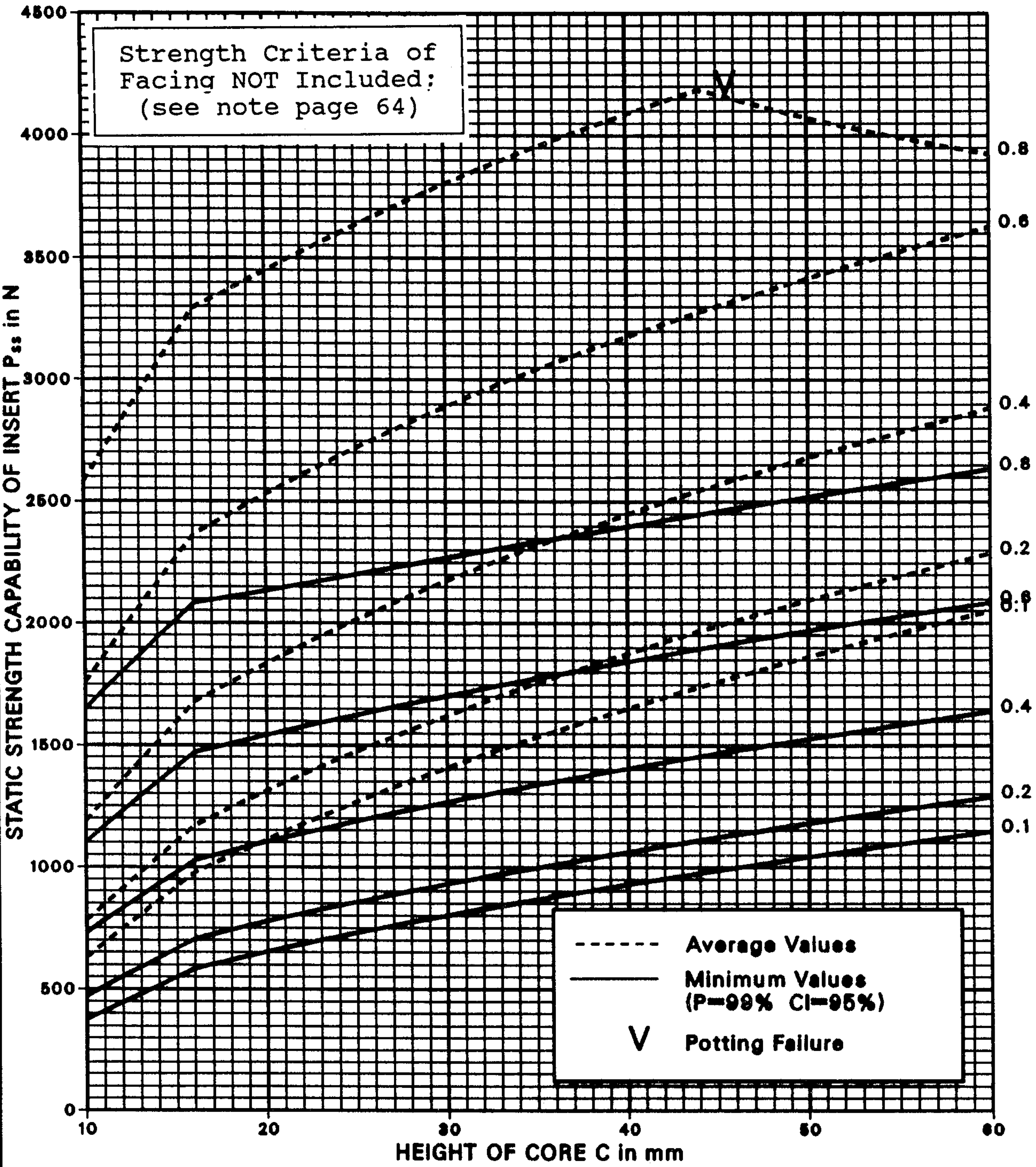


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Tension**

Insert Diameter: **14.0 mm**

Core : **HRH 10-1/8-3.0**

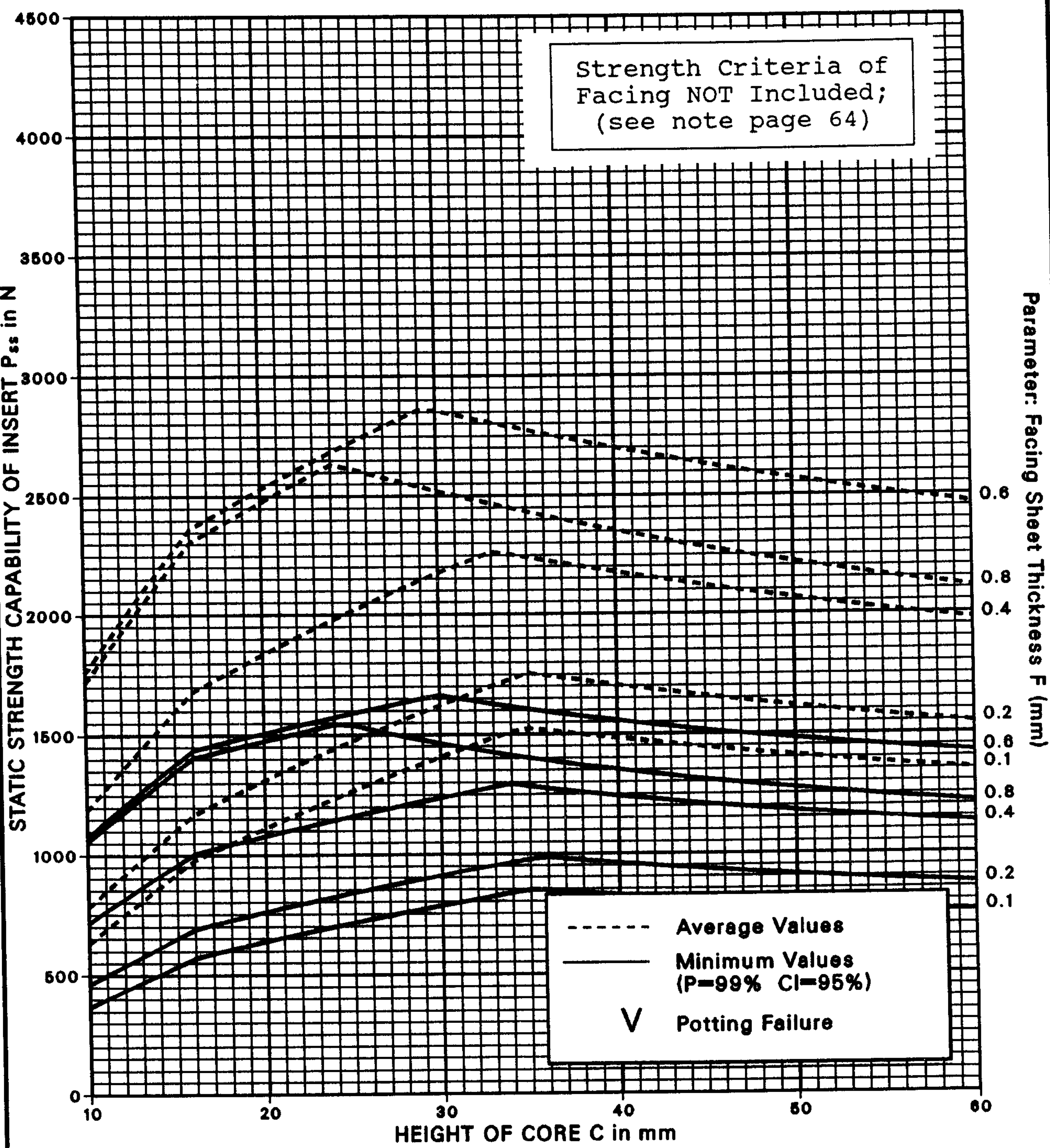


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Compression**

Insert Diameter: **14.0 mm**

Core : **HRH 10-1/8-3.0**

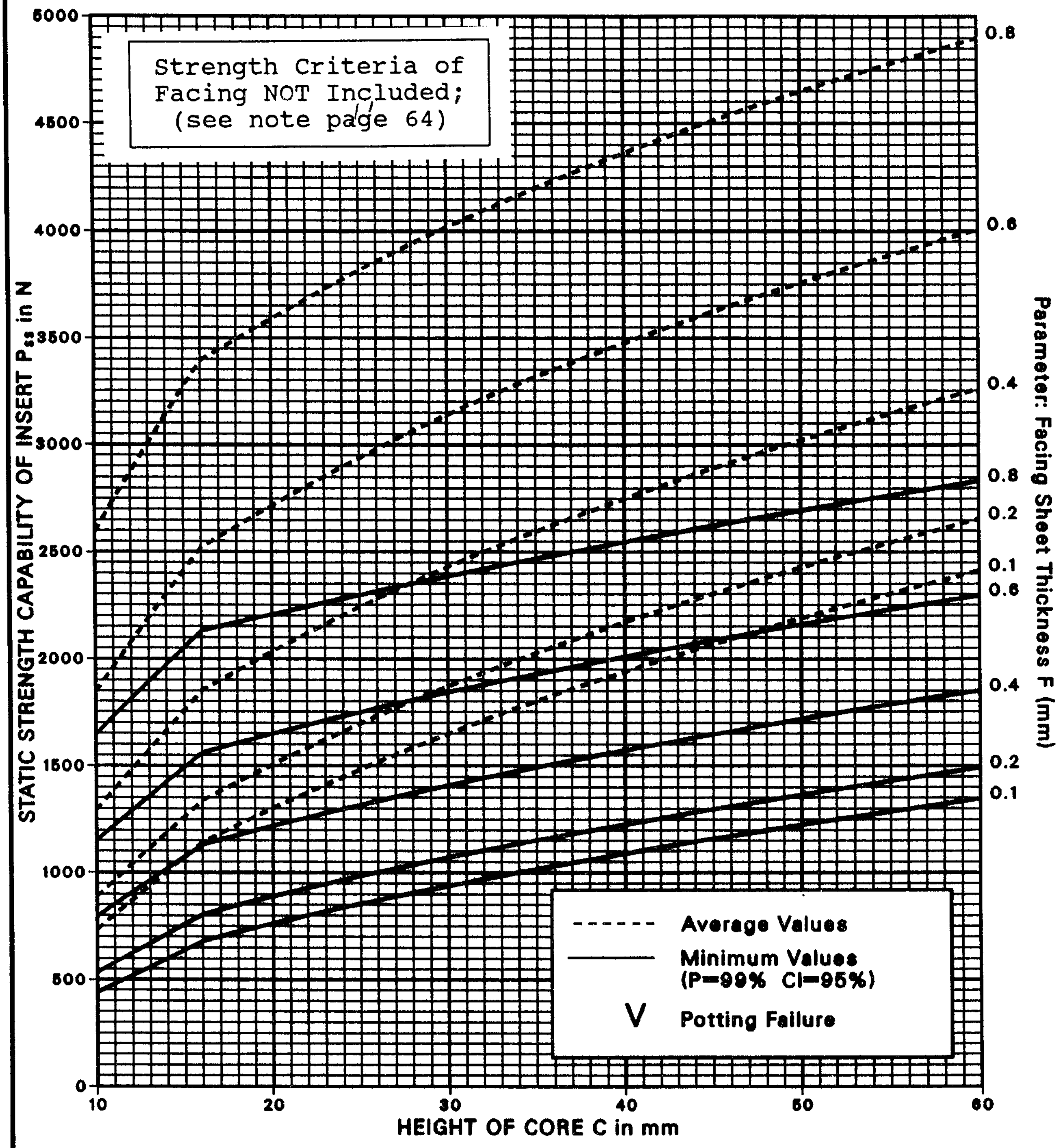


Insert Height h = 9 mm **Facing Material AL 2024**

Load : **Tension**

Insert Diameter: **17.5 mm**

Core : **HRH 10-1/8-3.0**

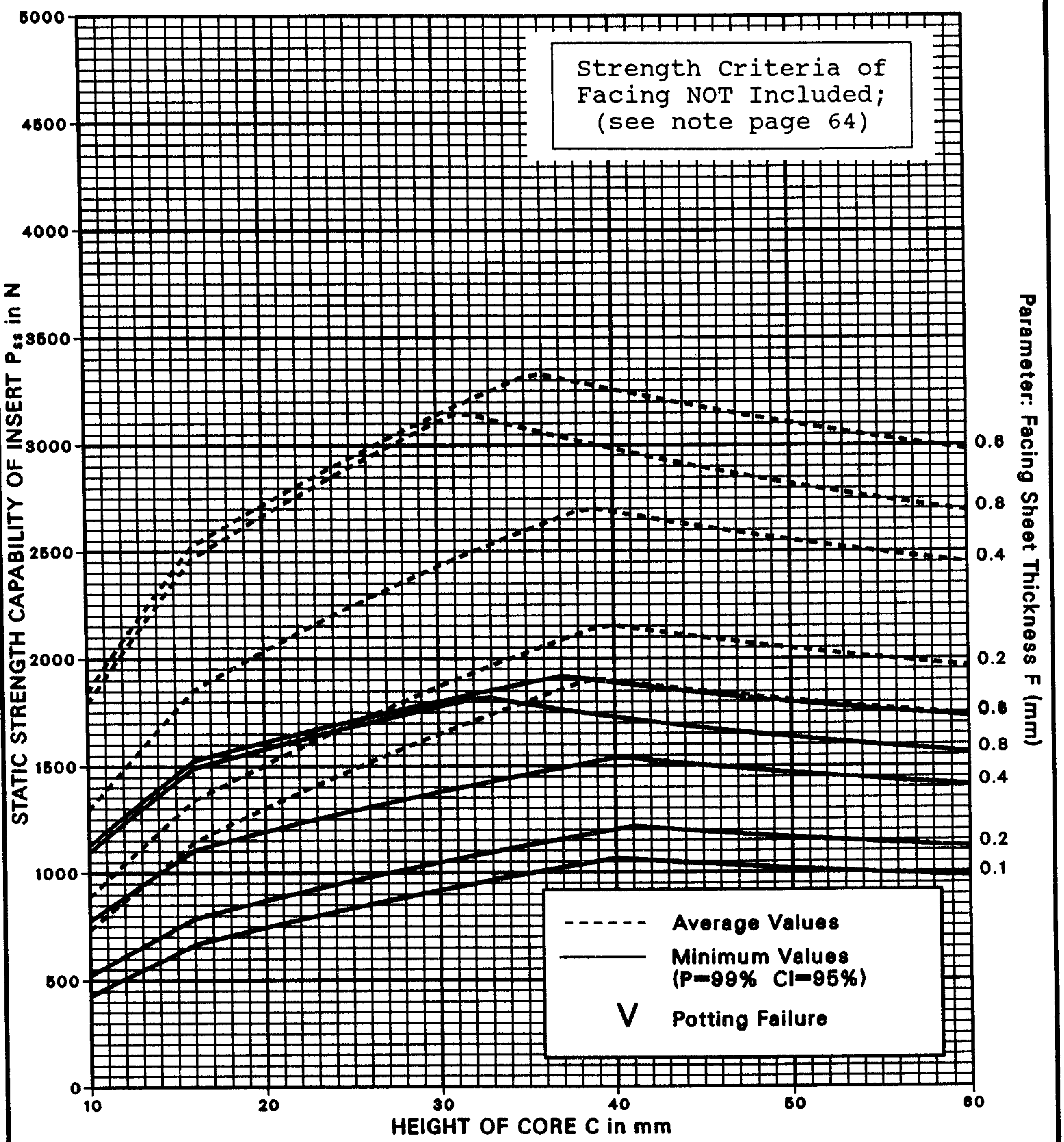


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Compression**

Insert Diameter: **17.5 mm**

Core : **HRH 10-1/8-3.0**

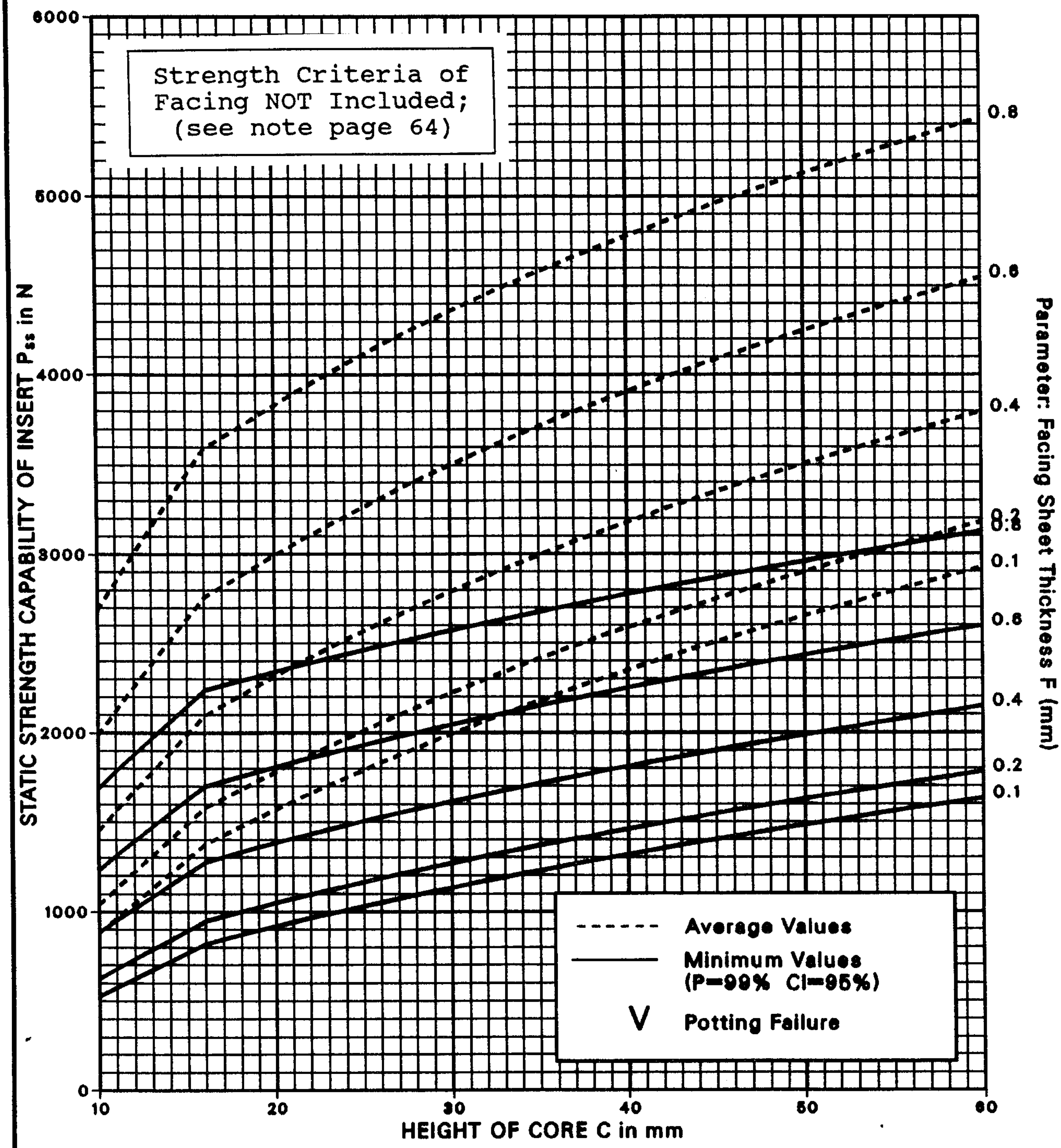


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **22.5 mm**

Core : **HRH 10-1/8-3.0**

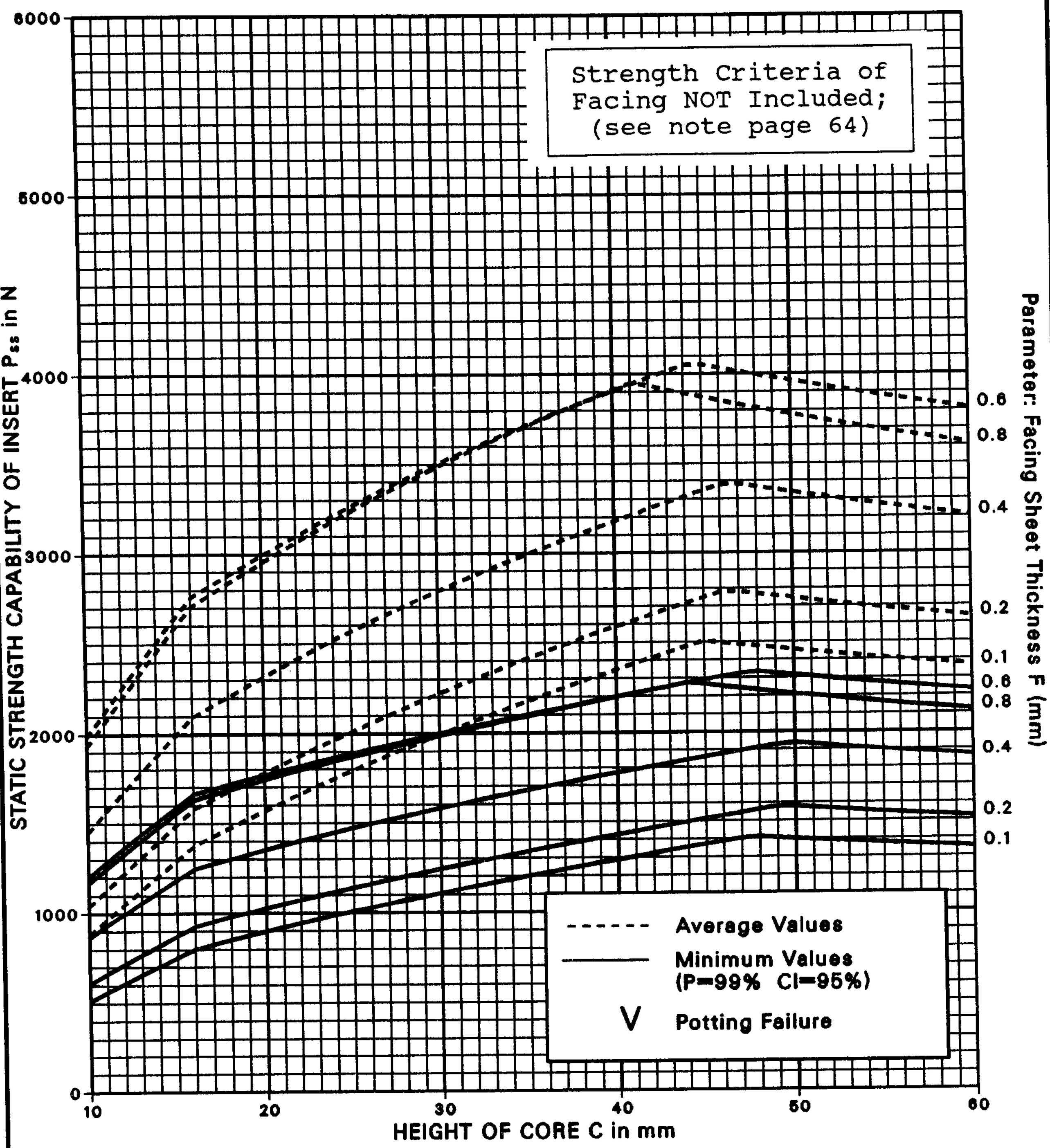


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Compression**

Insert Diameter: **22.5 mm**

Core : **HRH 10-1/8-3.0**



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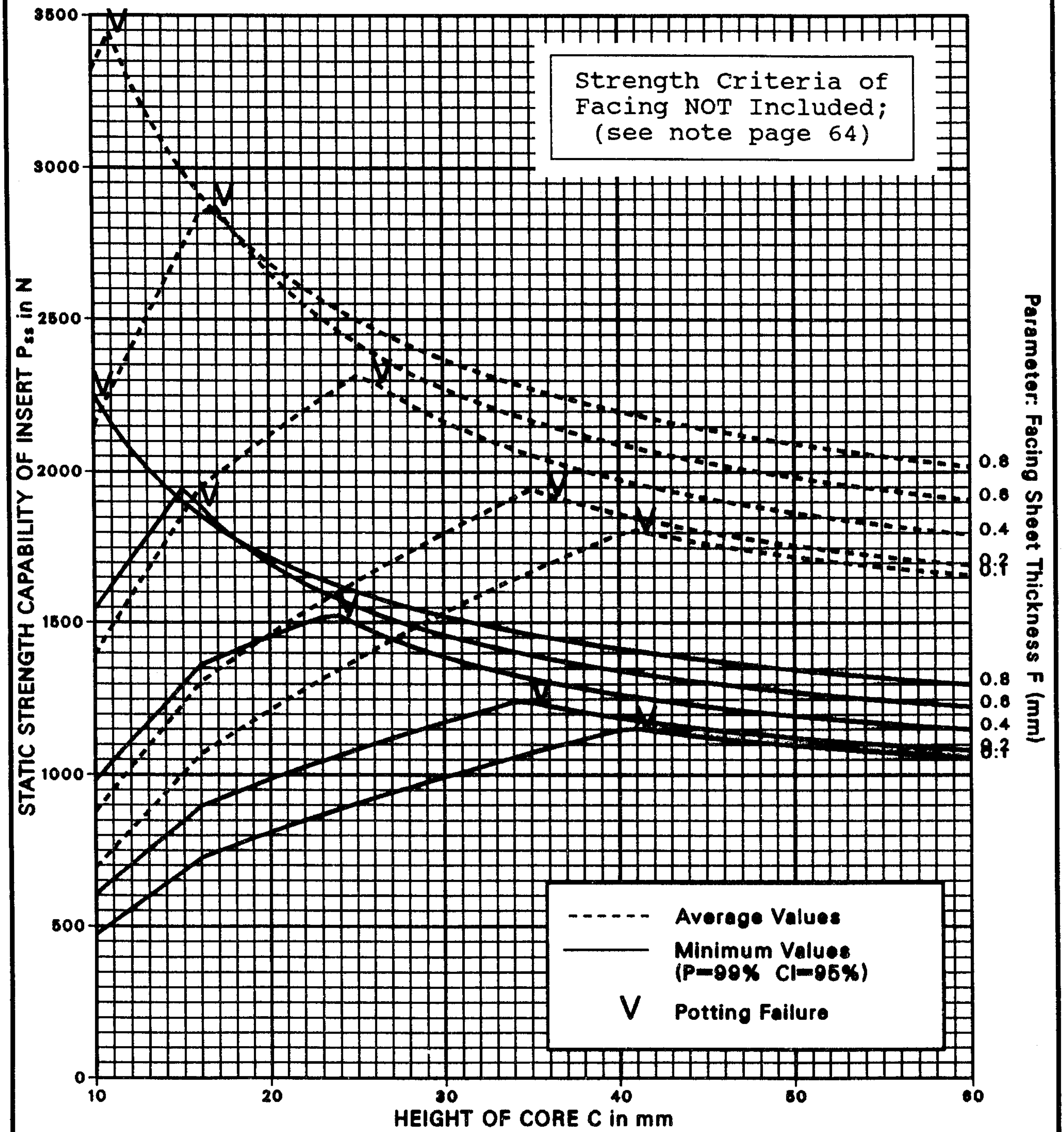
14. HRH 10 – 1/8 – 4.0 Core

Insert Height h = 9 mm | Facing Material AL 2024

Load : Tension

Insert Diameter: 9.0 mm

Core : HRH 10-1/8-4.0

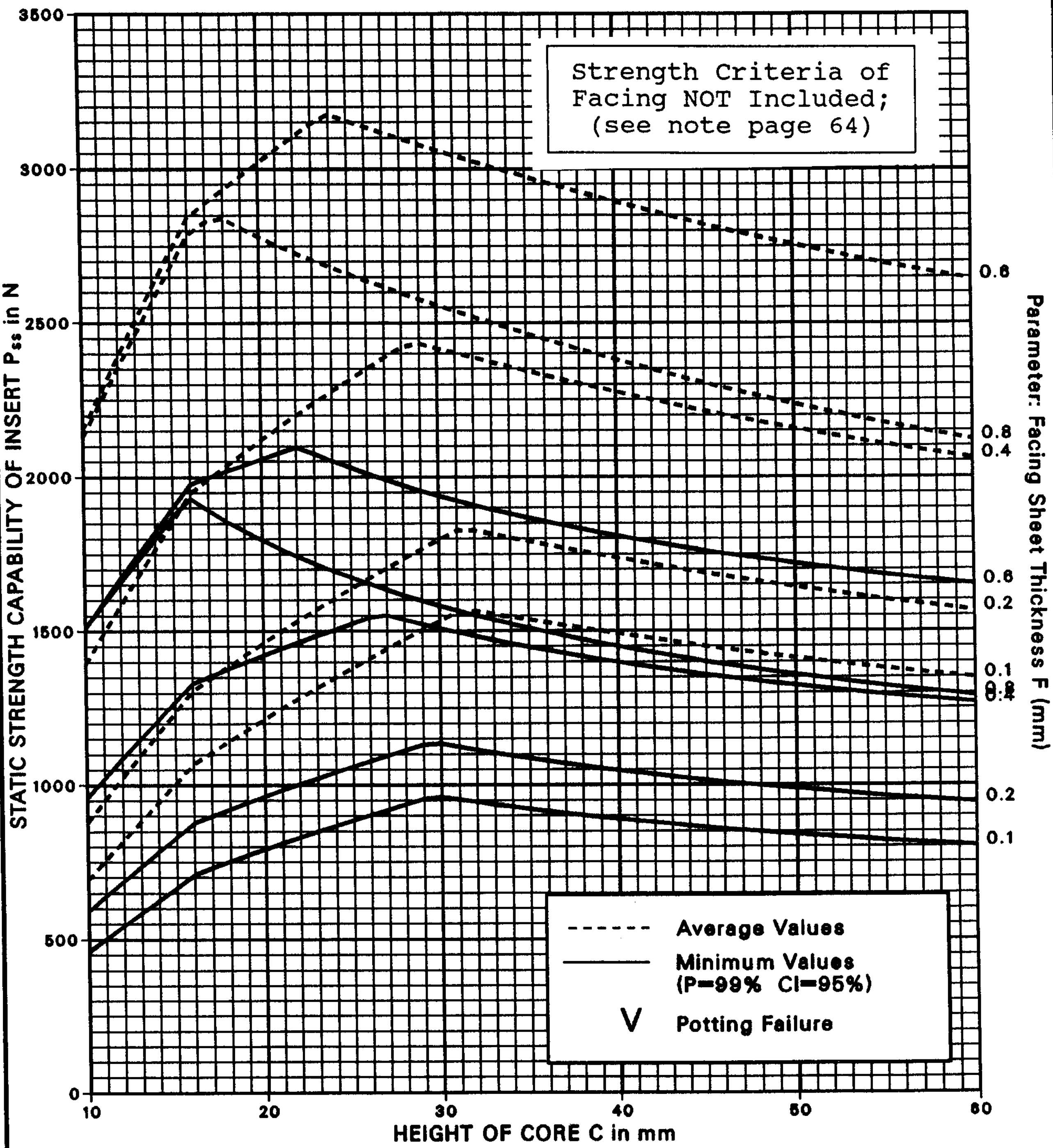


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Compression**

Insert Diameter: **9.0 mm**

Core : **HRH 10-1/8-4.0**

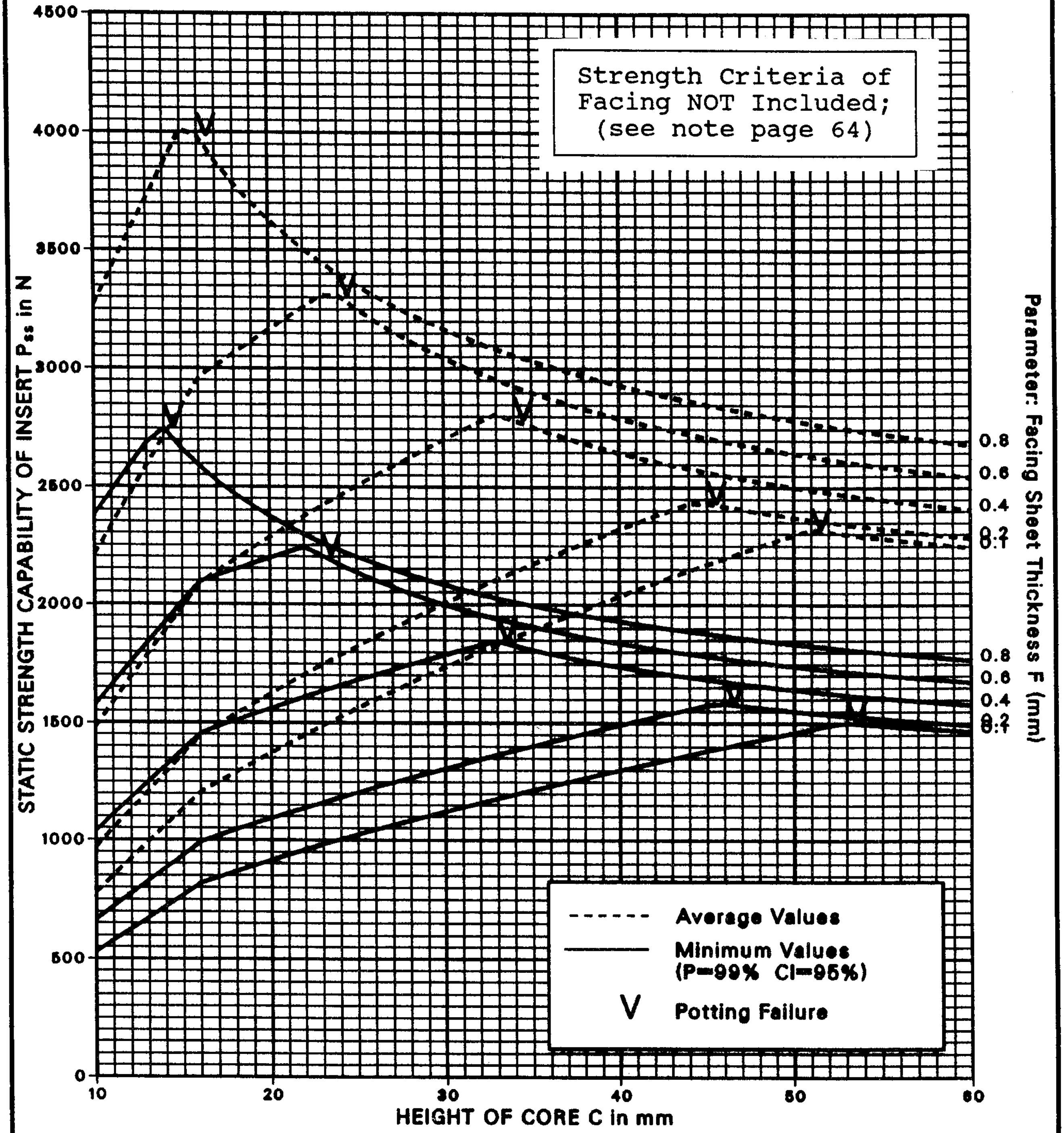


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **11.0 mm**

Core : **HRH 10-1/8-4.0**

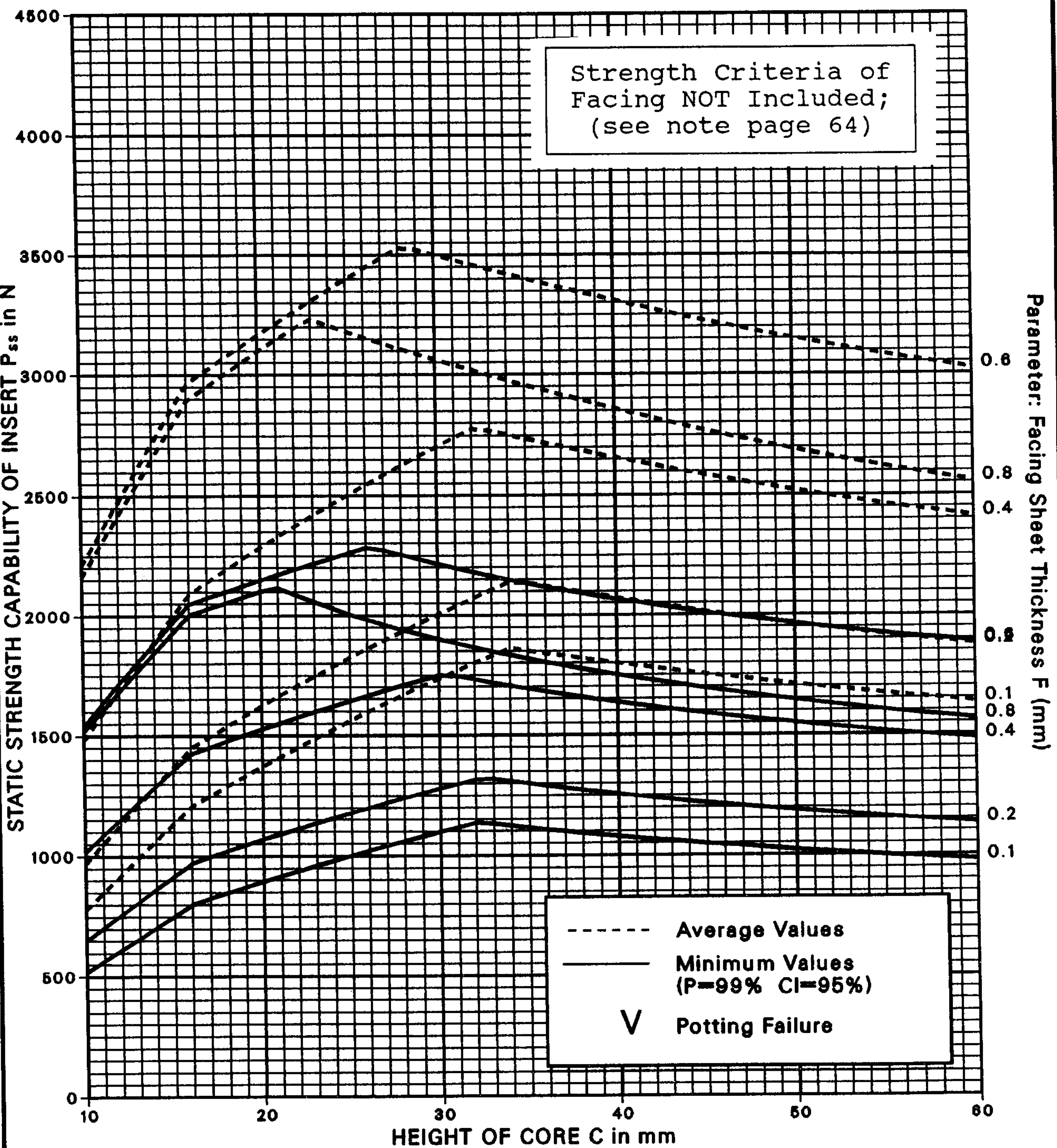


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 11.0 mm

Core : HRH 10-1/8-4.0

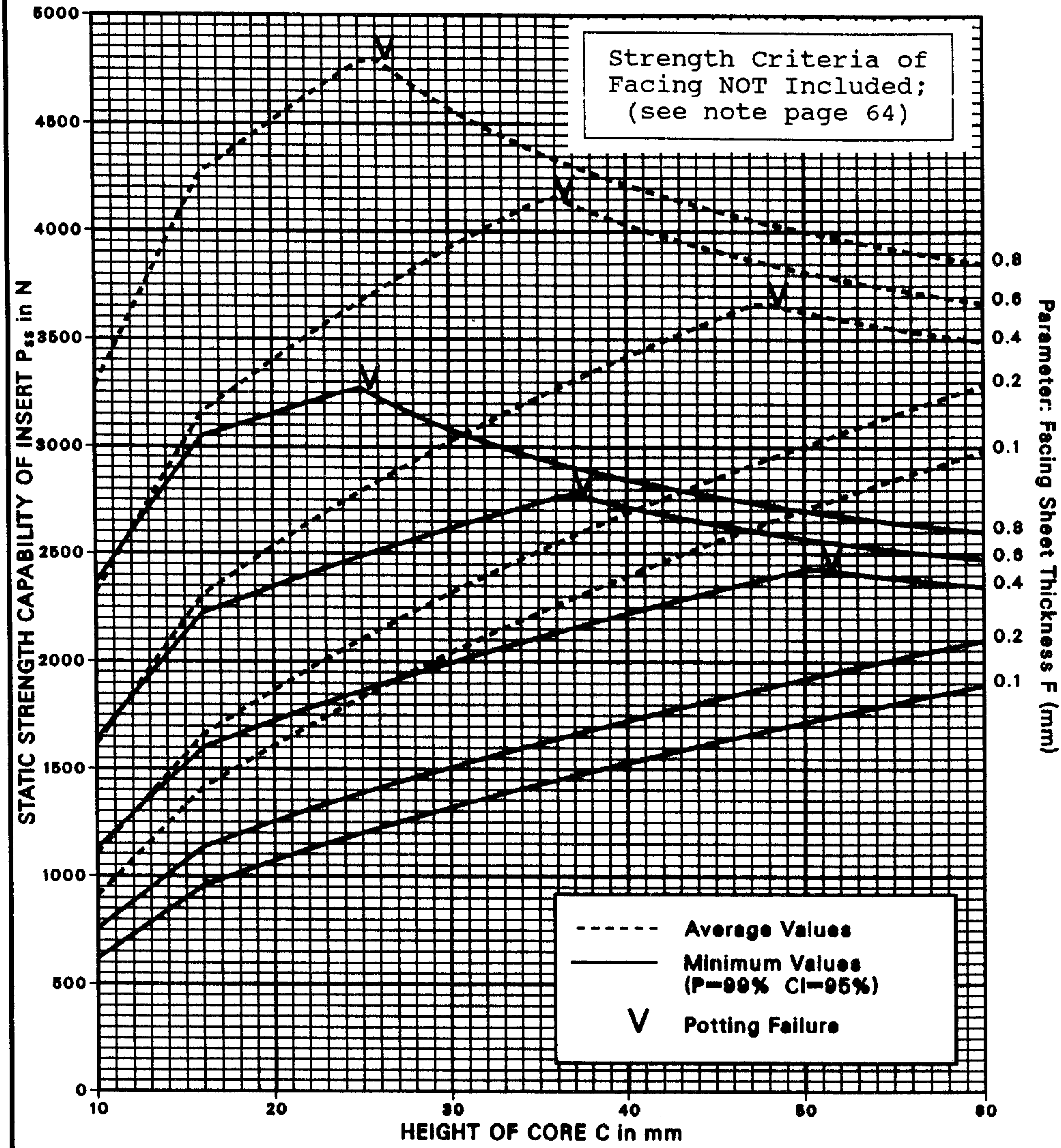


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Tension**

Insert Diameter: **14.0 mm**

Core : **HRH 10-1/8-4.0**

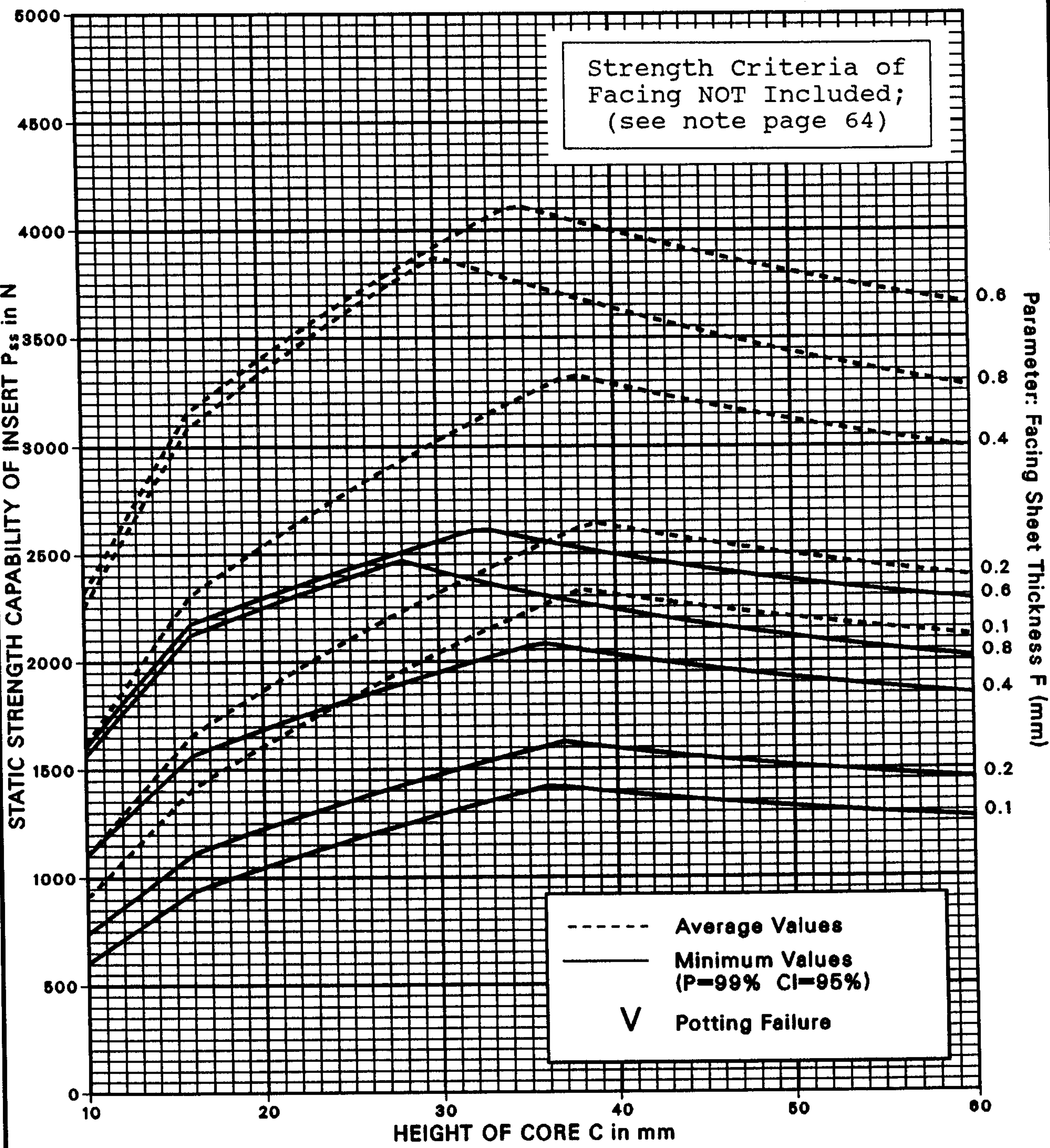


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Compression**

Insert Diameter: **14.0 mm**

Core : **HRH 10-1/8-4.0**



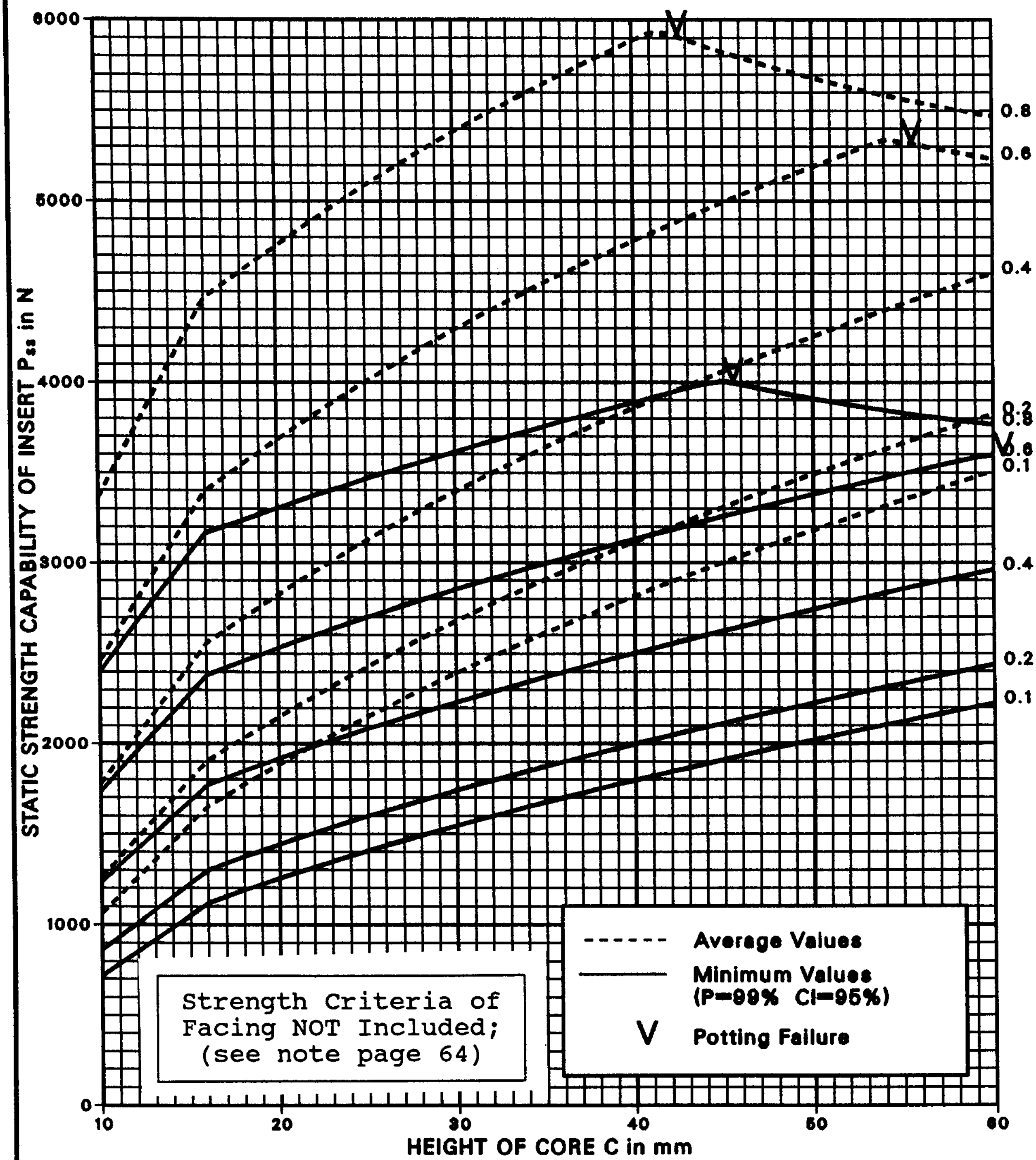
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **17.5 mm**

Core : **HRH 10-1/8-4.0**

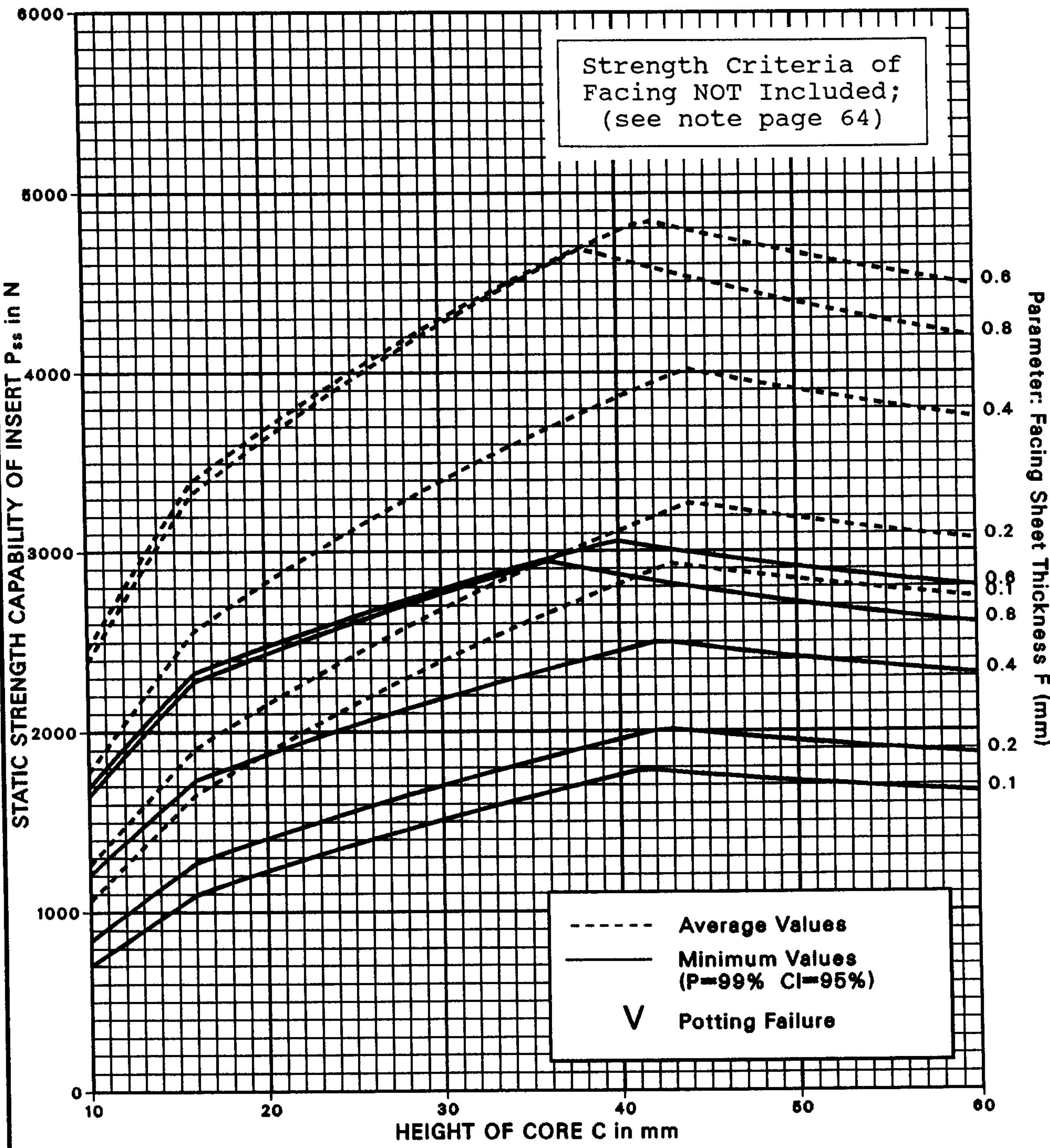


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Compression**

Insert Diameter: **17.5 mm**

Core : **HRH 10-1/8-4.0**

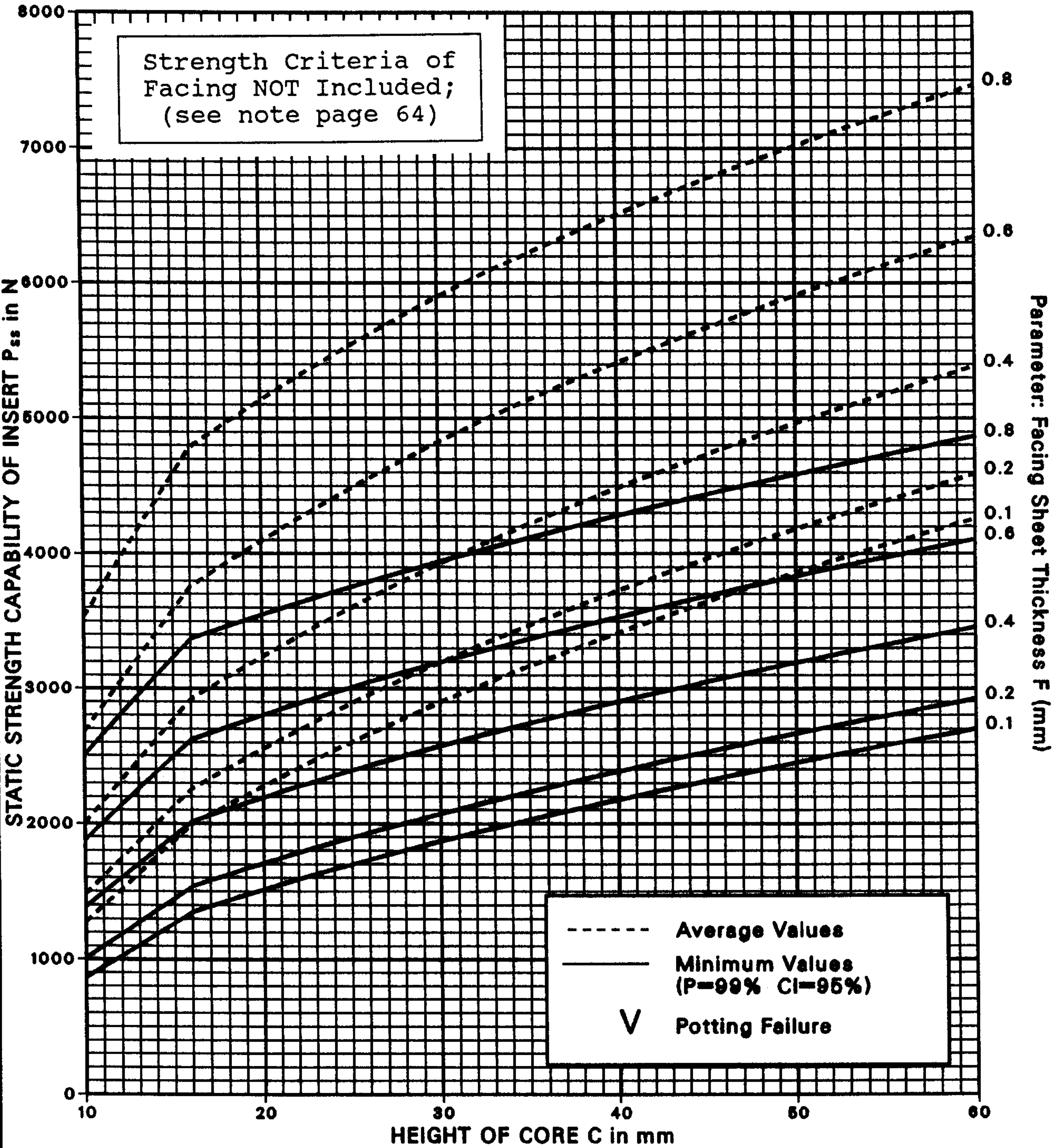


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **22.5 mm**

Core : **HRH 10-1/8-4.0**

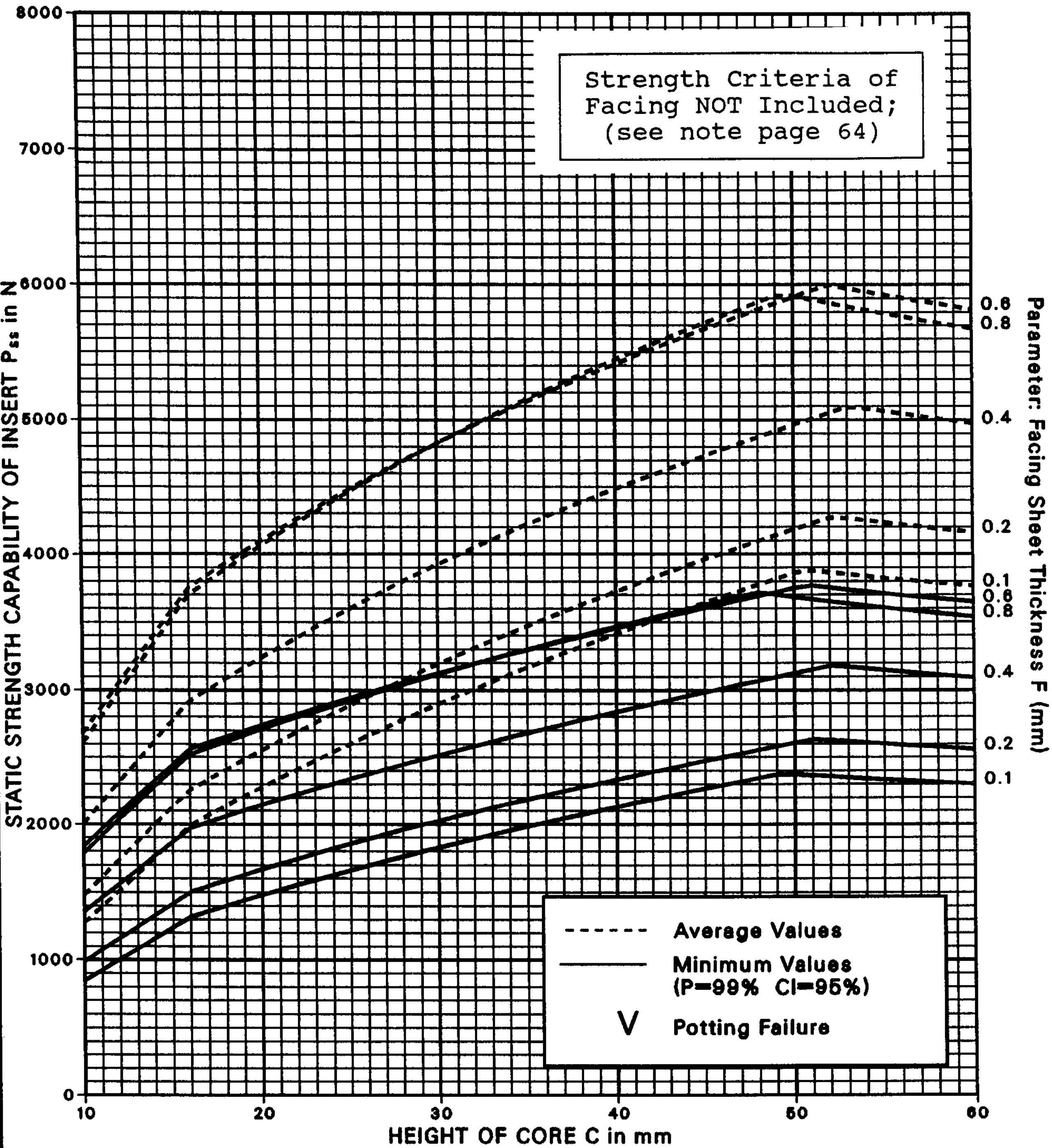


Insert Height h = 9 mm Facing Material AL 2024

Load : Compression

Insert Diameter: 22.5 mm

Core : HRH 10-1/8-4.0



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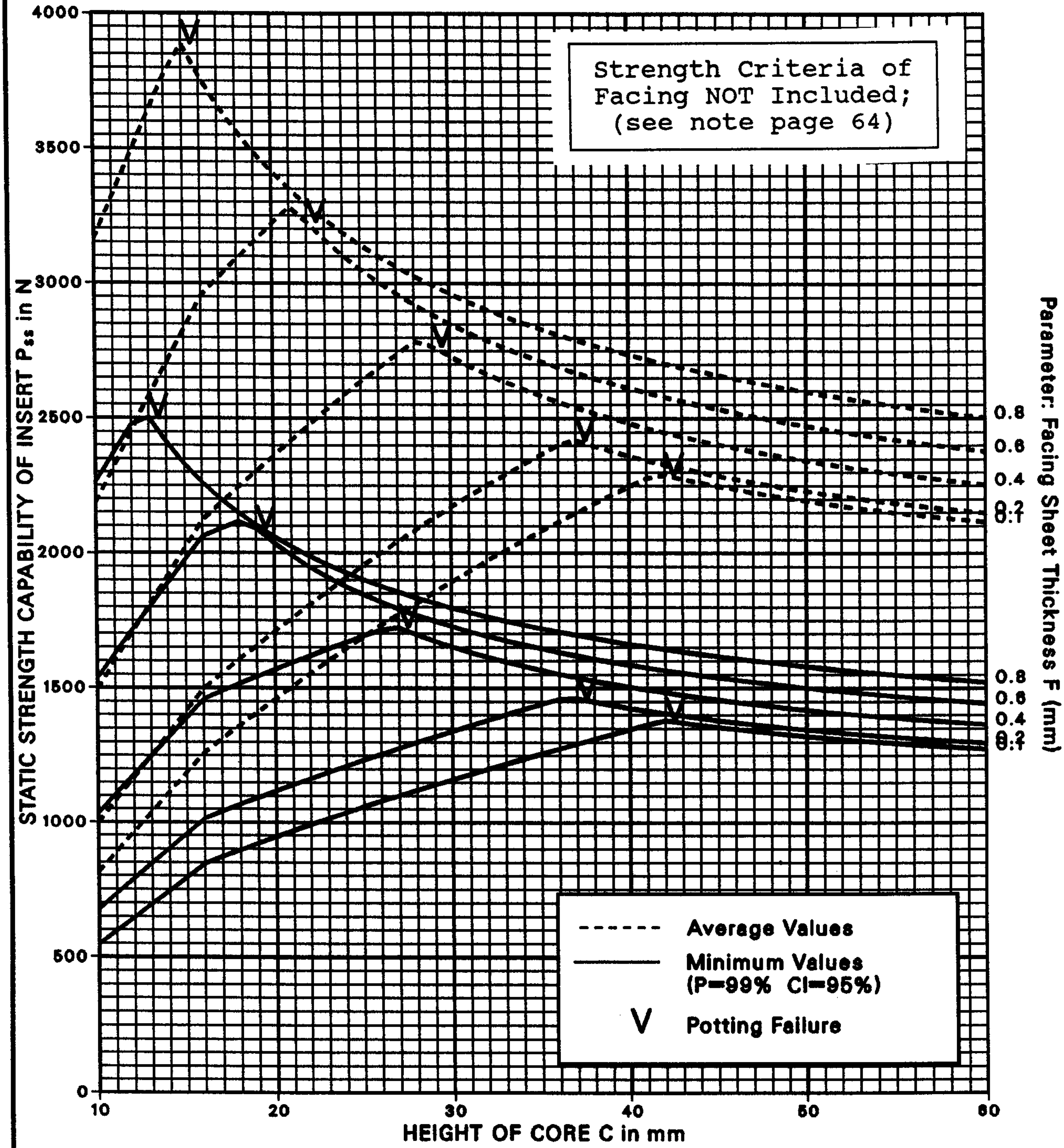
15. HRP – 3/16 – 4.0 Core

Insert Height h = 9 mm	Facing Material AL 2024

Load : **Tension**

Insert Diameter: **9.0 mm**

Core : **HRP-3/16-4.0**

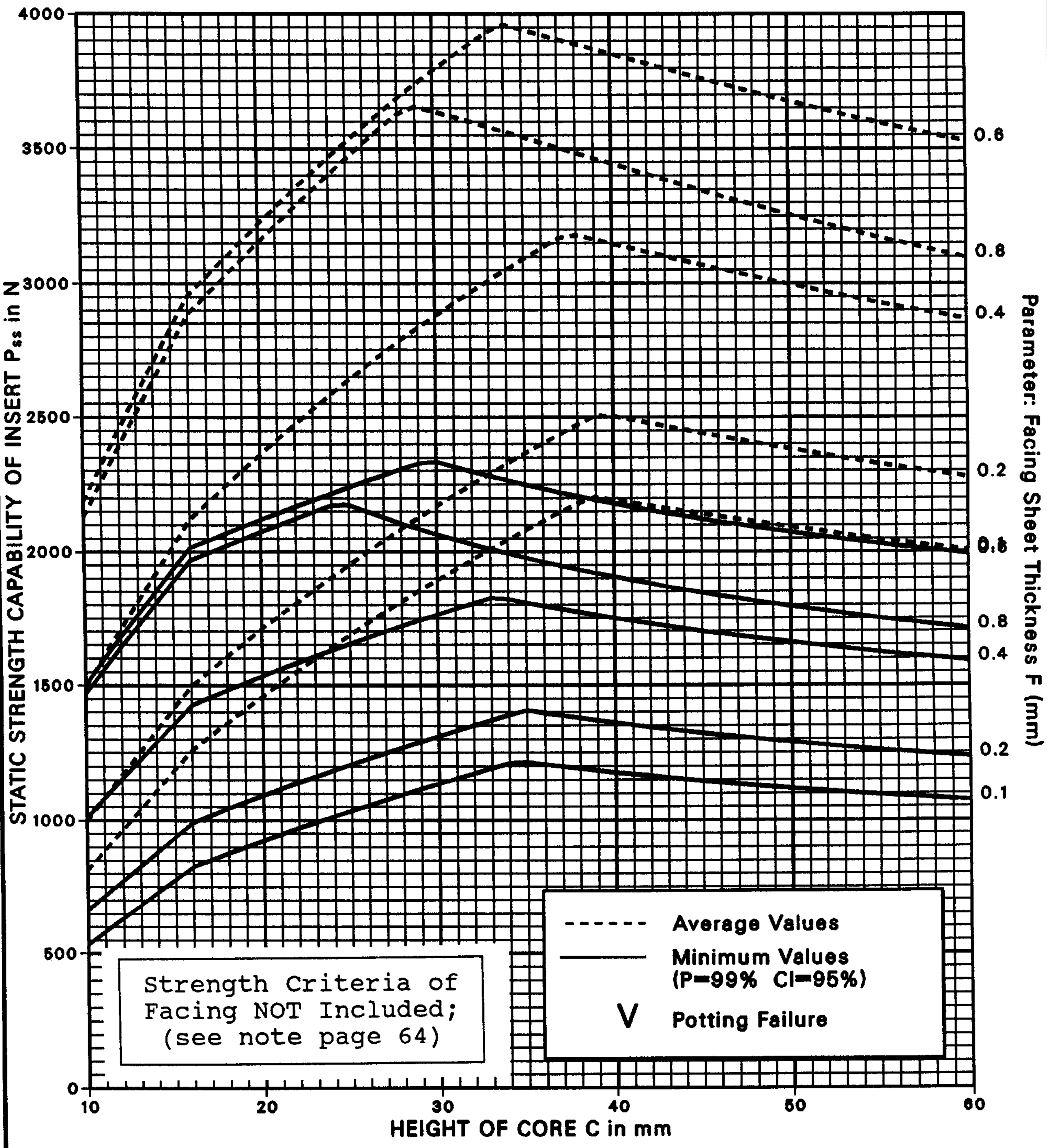


Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression

Insert Diameter: 9.0 mm

Core : HRP-3/16-4.0

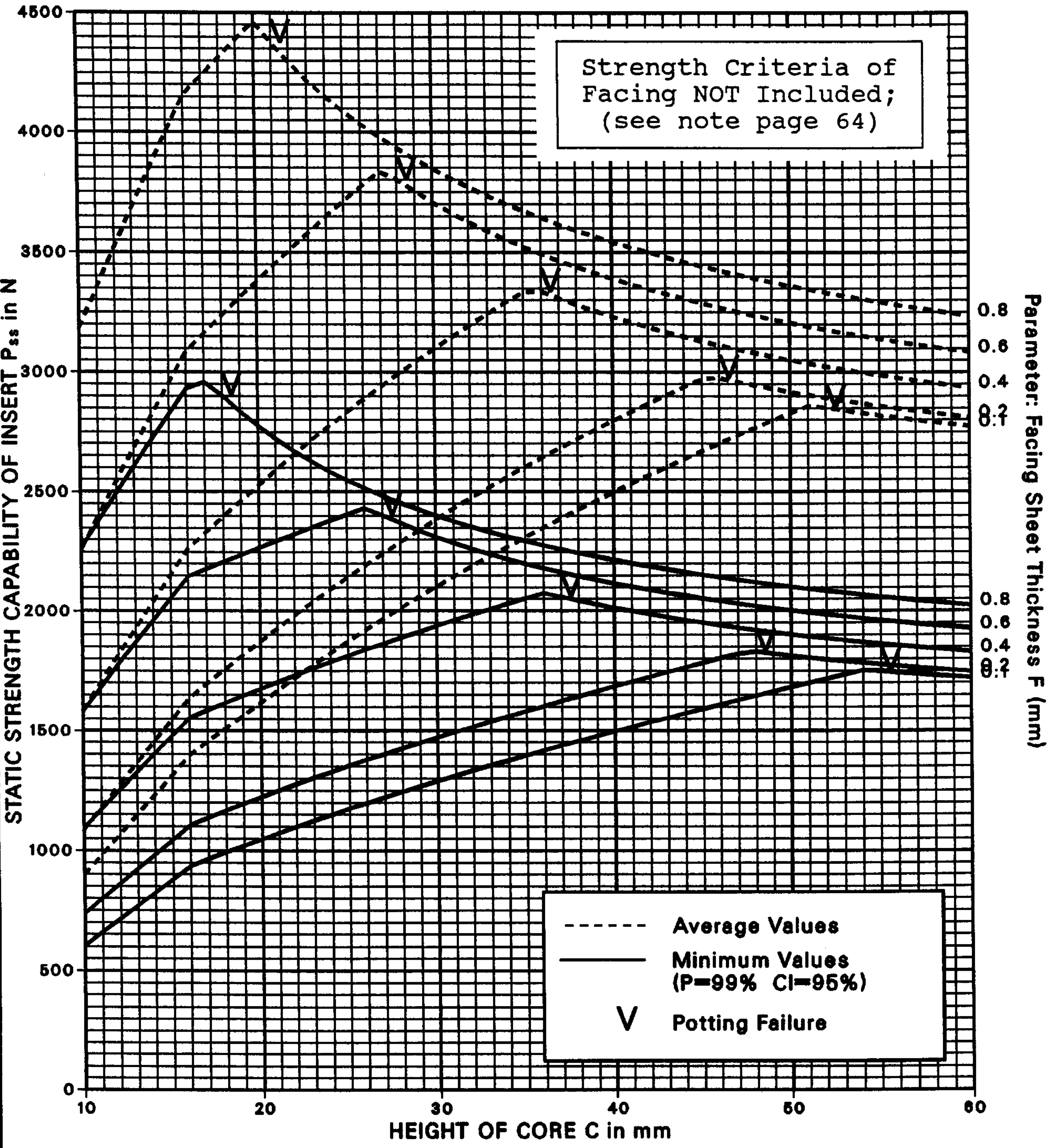


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Tension**

Insert Diameter: **11.0 mm**

Core : **HRP-3/16-4.0**

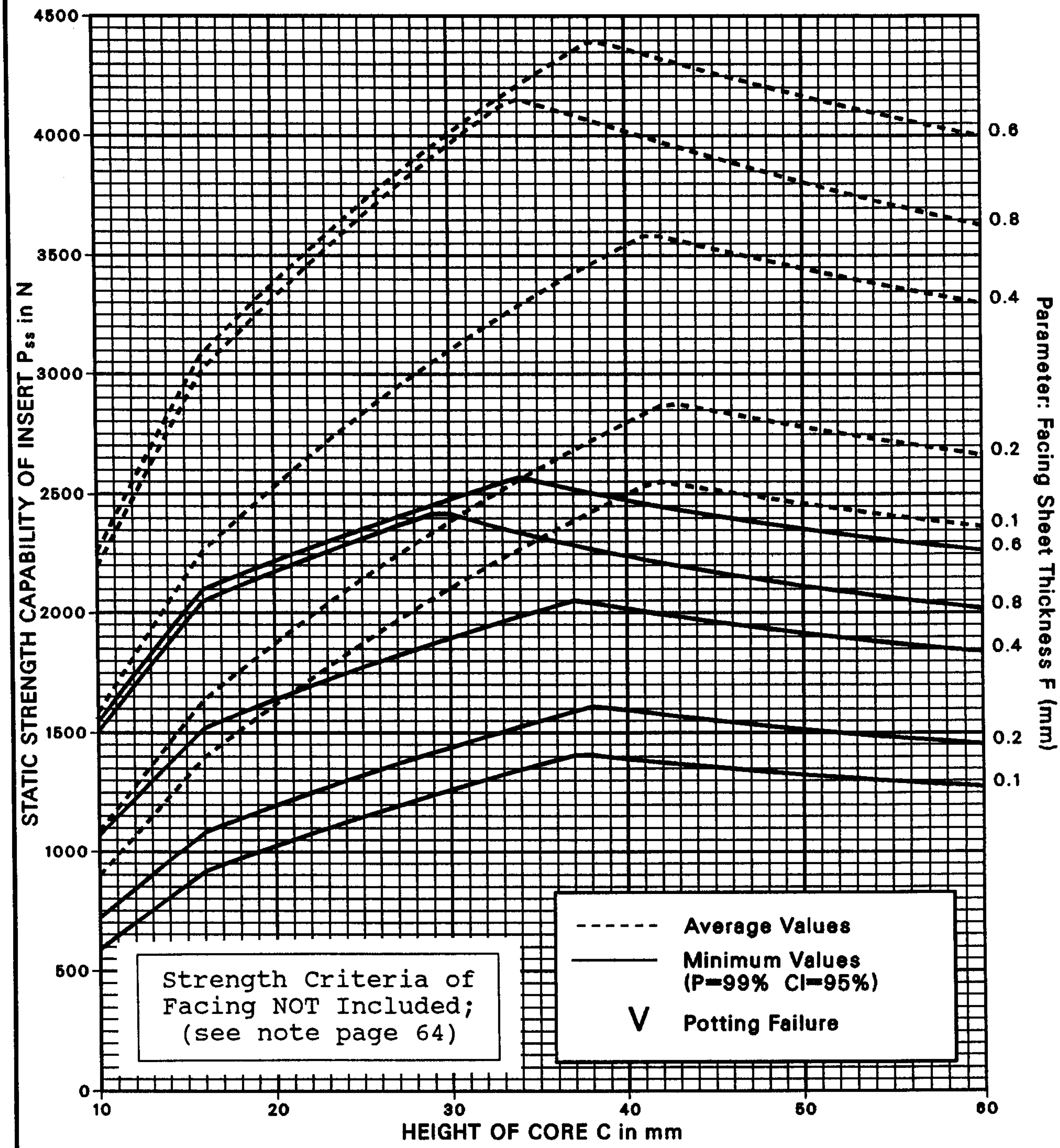


Insert Height h = 9 mm Facing Material AL 2024

Load : **Compression**

Insert Diameter: **11.0 mm**

Core : **HRP-3/16-4.0**



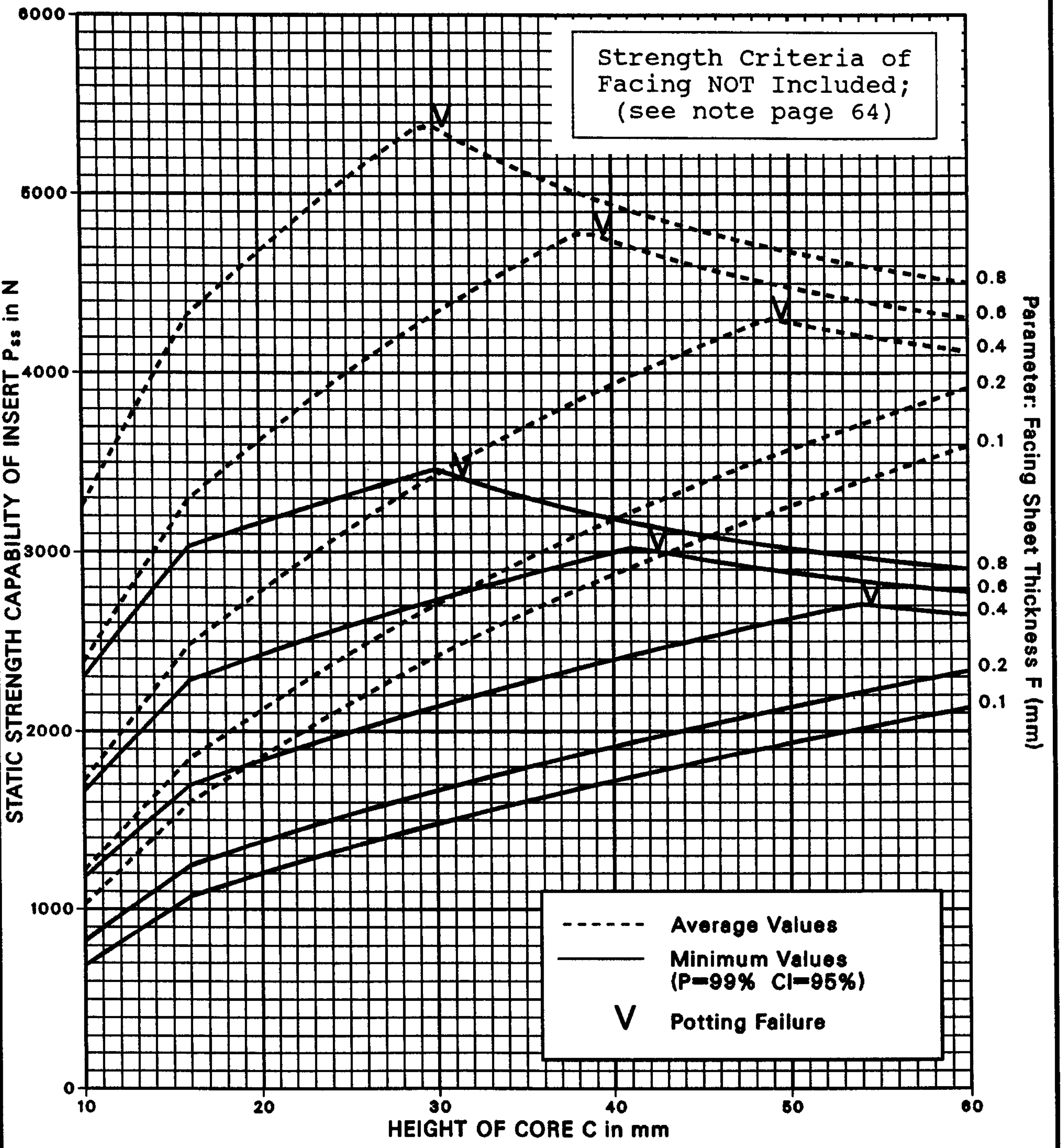
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

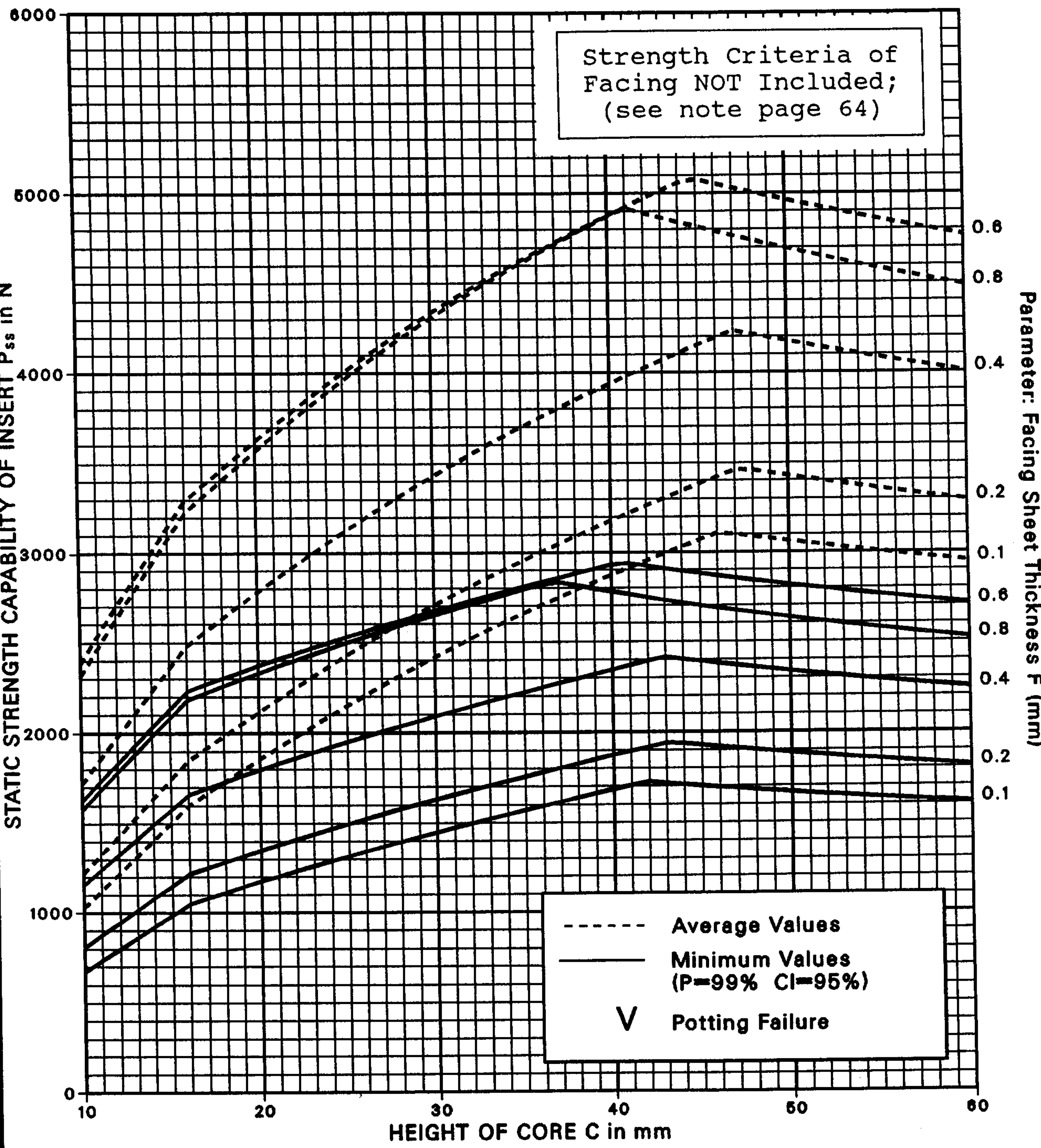
Insert Diameter: **14.0 mm**

Core : **HRP-3/16-4.0**



Insert Height h = 9 mm | Facing Material AL 2024

Load : Compression
Insert Diameter: 14.0 mm
Core : HRP-3/16-4.0

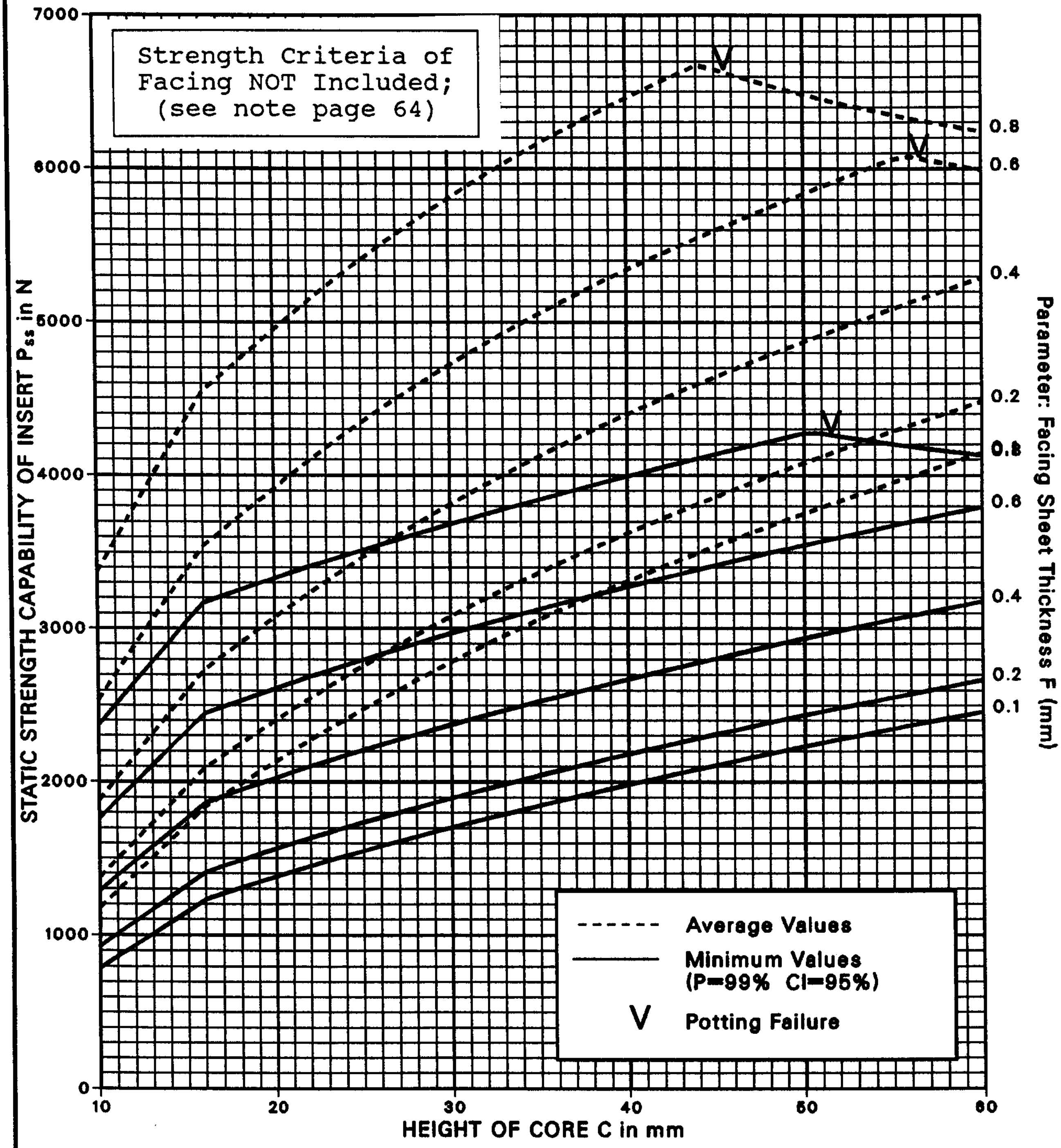


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **17.5 mm**

Core : **HRP-3/16-4.0**

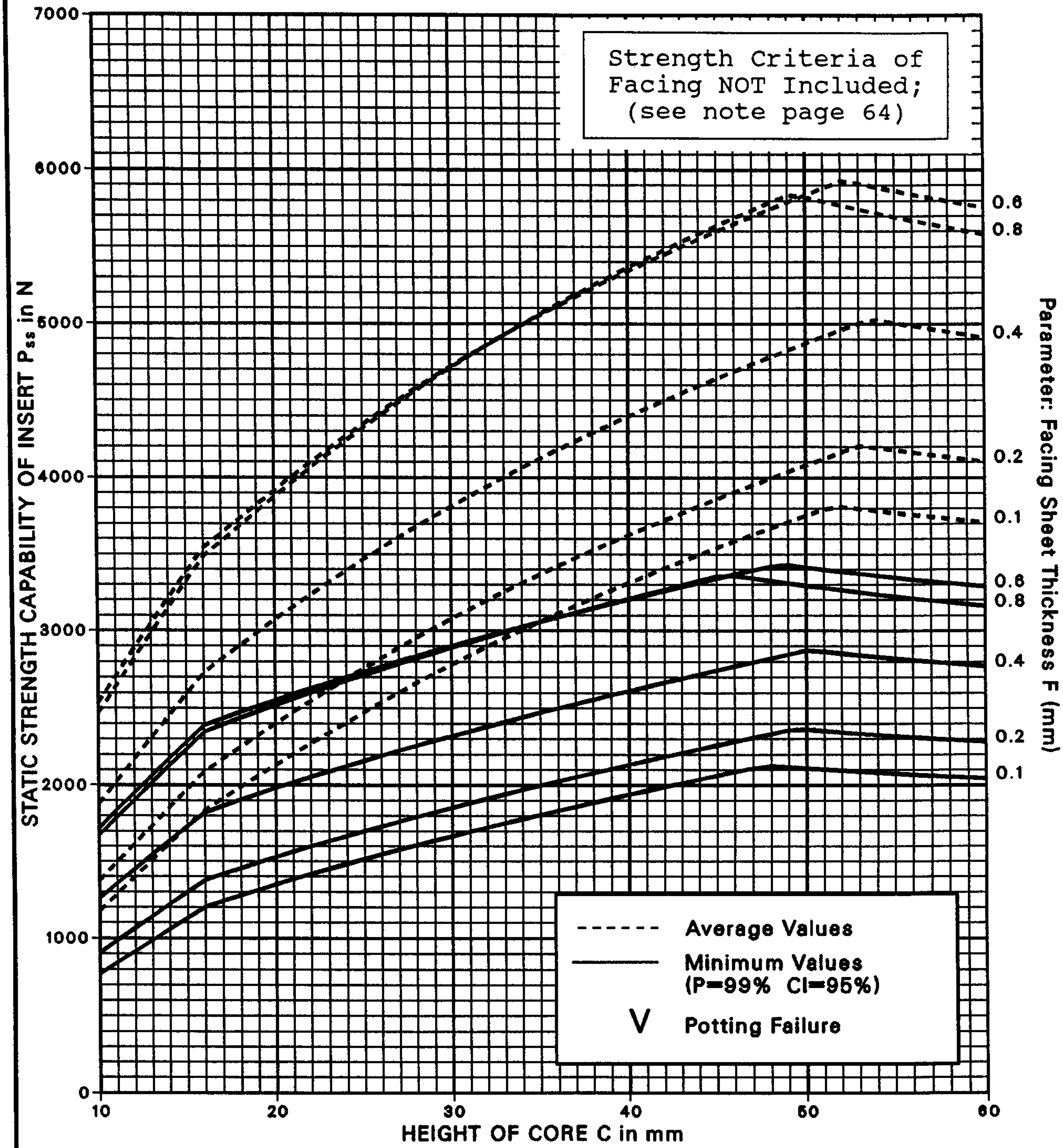


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Compression**

Insert Diameter: **17.5 mm**

Core : **HRP-3/16-4.0**

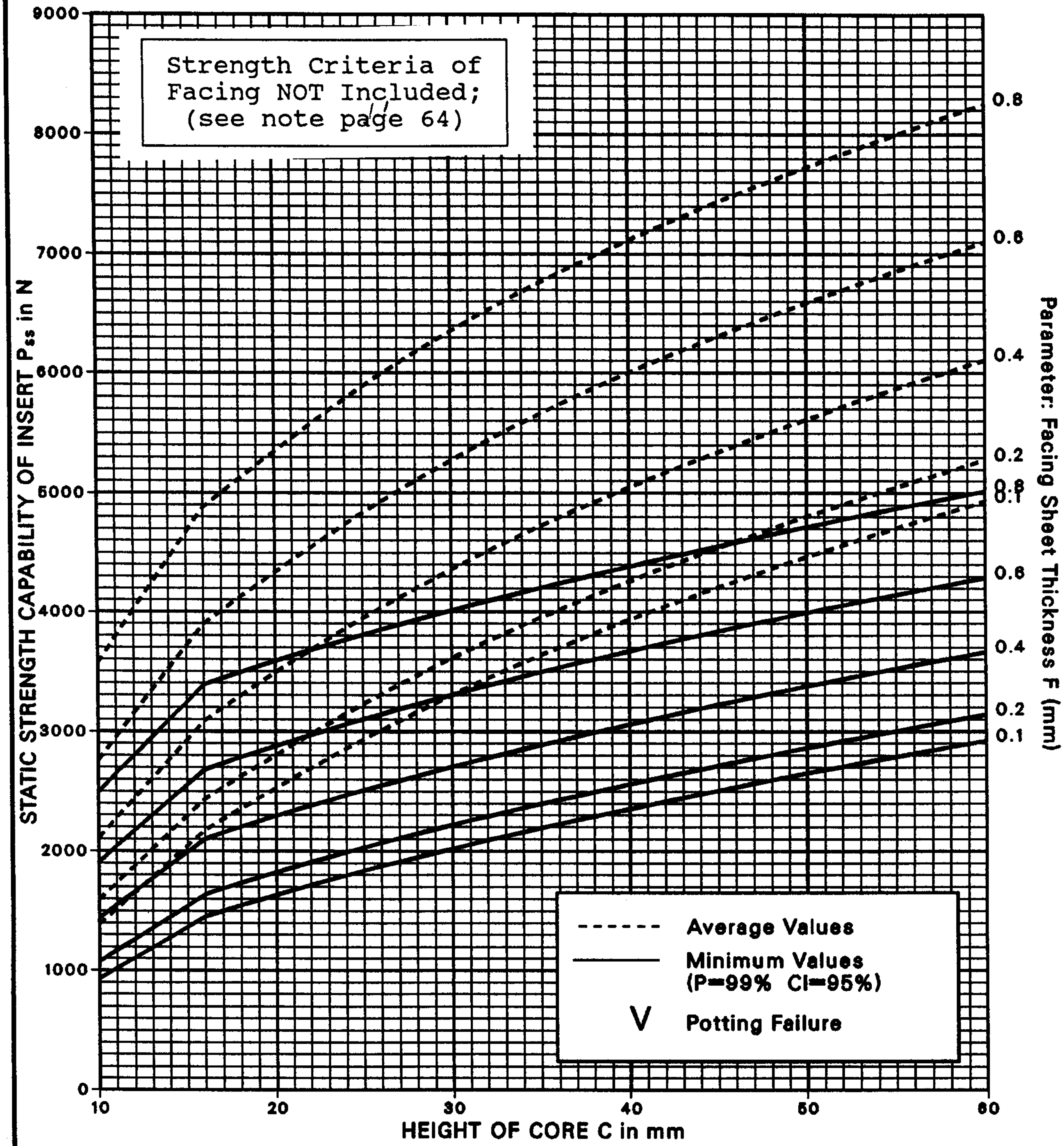


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **22.5 mm**

Core : **HRP-3/16-4.0**

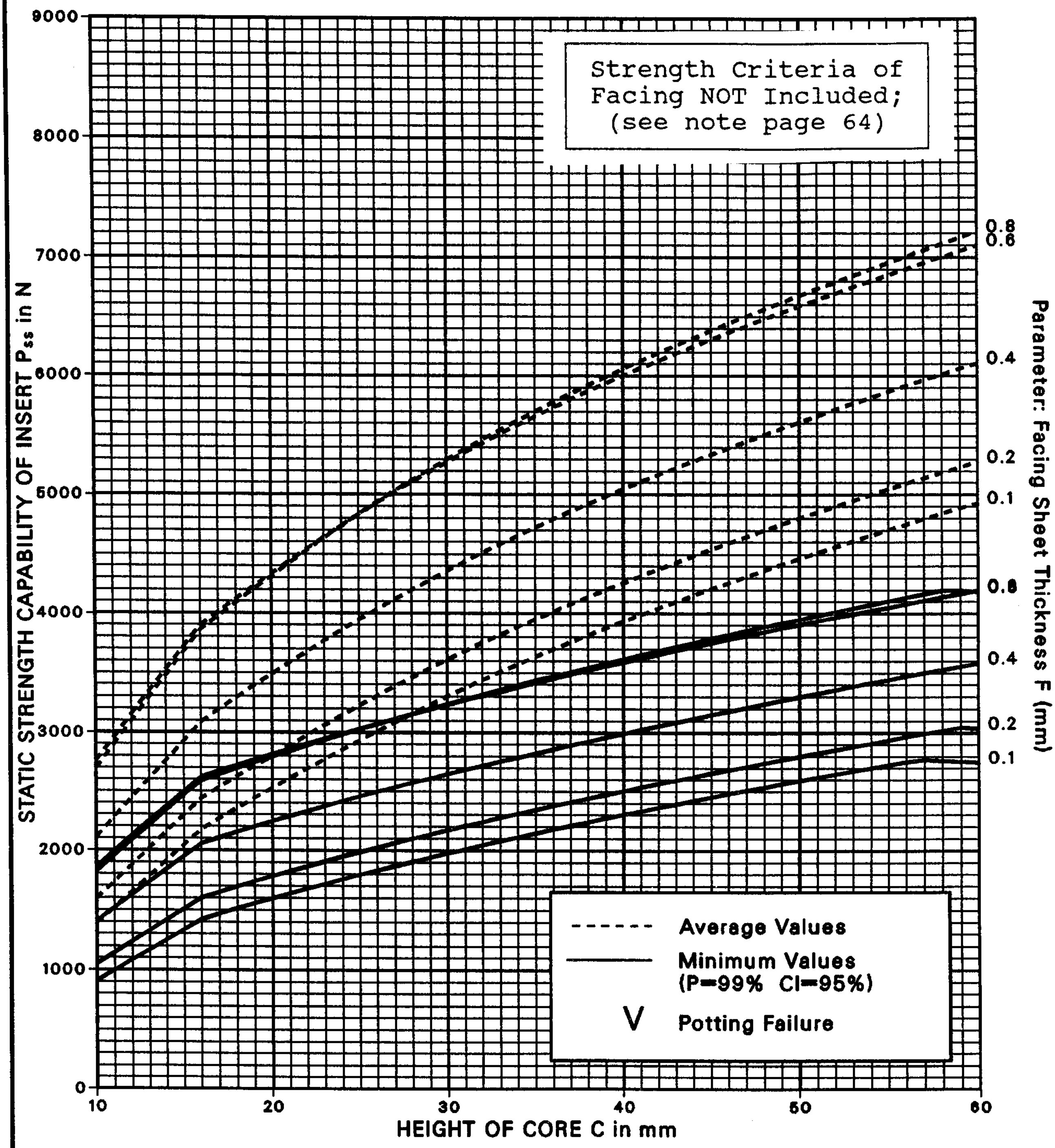


Insert Height h = 9 mm Facing Material AL 2024

Load : **Compression**

Insert Diameter: **22.5 mm**

Core : **HRP-3/16-4.0**



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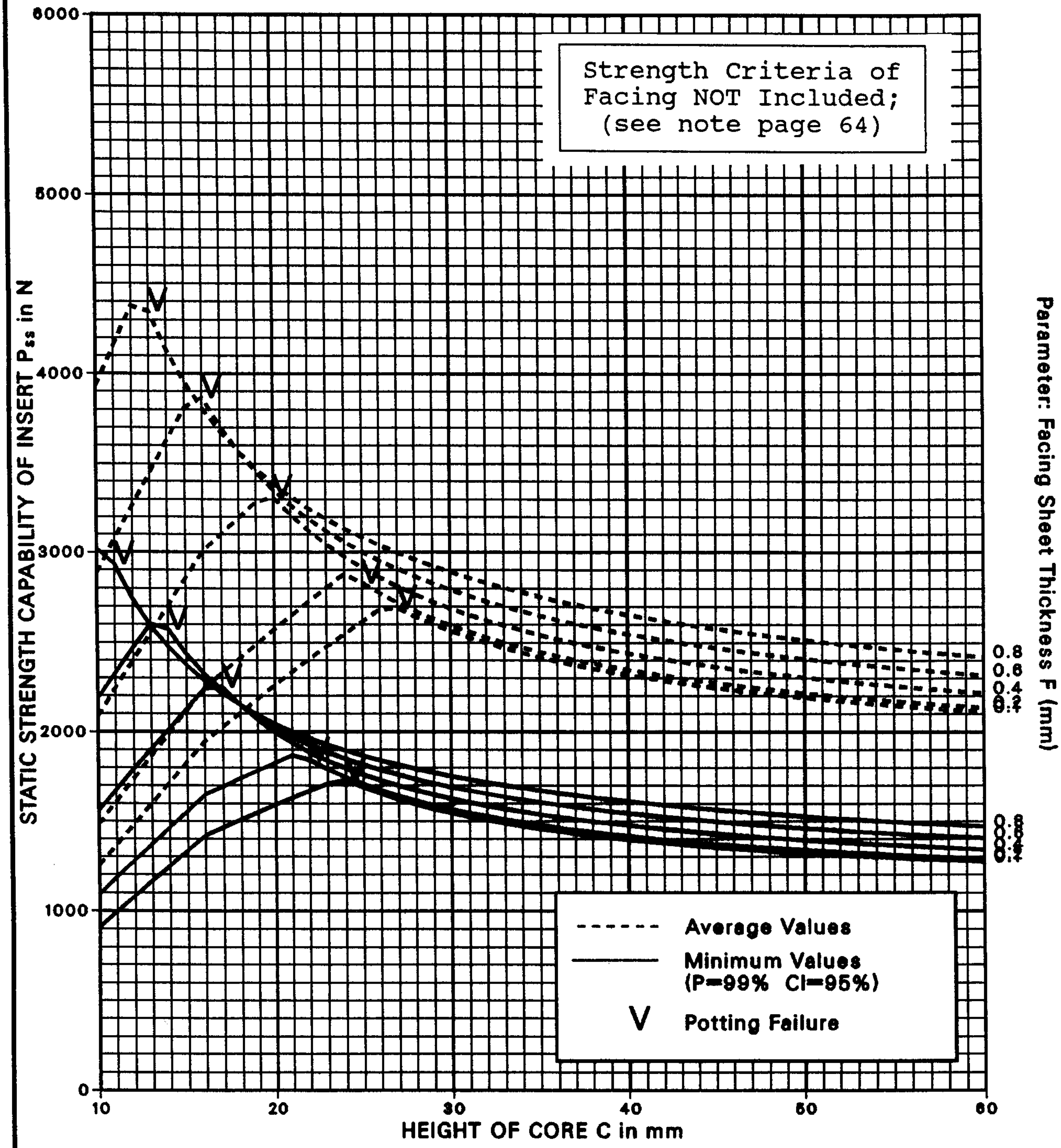
16. HRP – 3/16 – 5.5 Core

Insert Height h = 9 mm   Facing Material AL 2024

Load : **Tension**

Insert Diameter: **9.0 mm**

Core : **HRP-3/16-5.5**

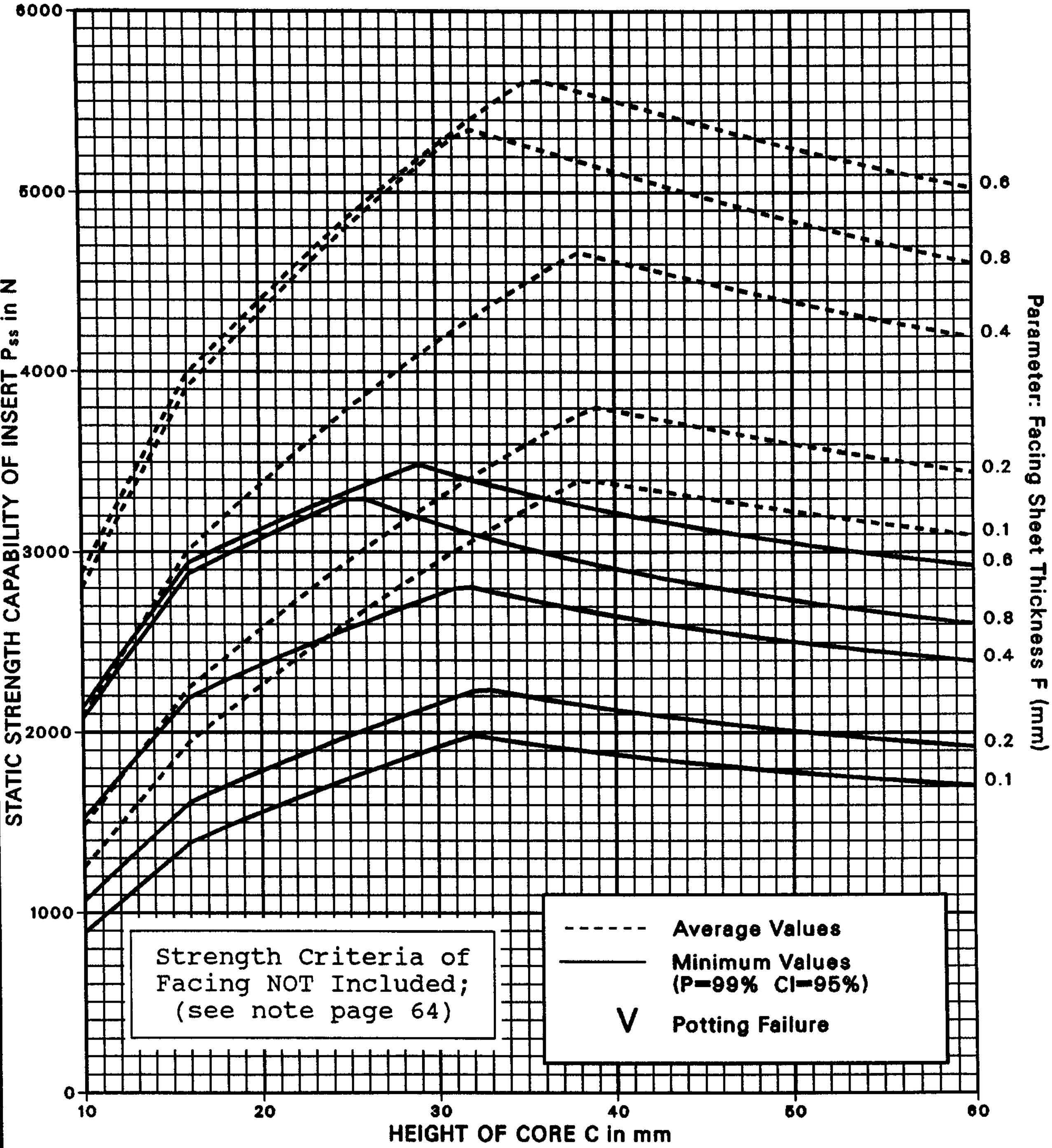


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Compression**

Insert Diameter: **9.0 mm**

Core : **HRP-3/16-5.5**

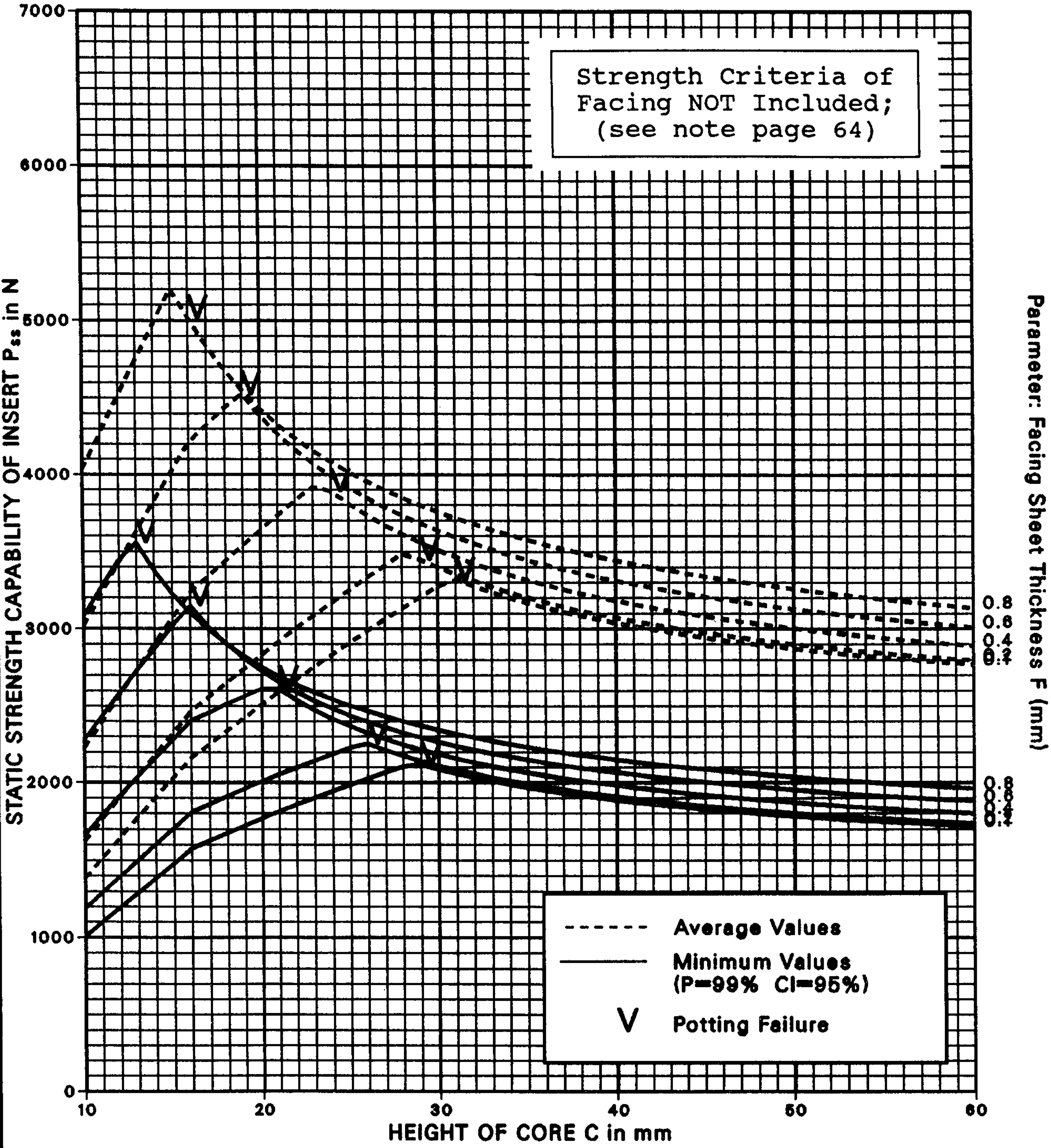


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **11.0 mm**

Core : **HRP-3/16-5.5**

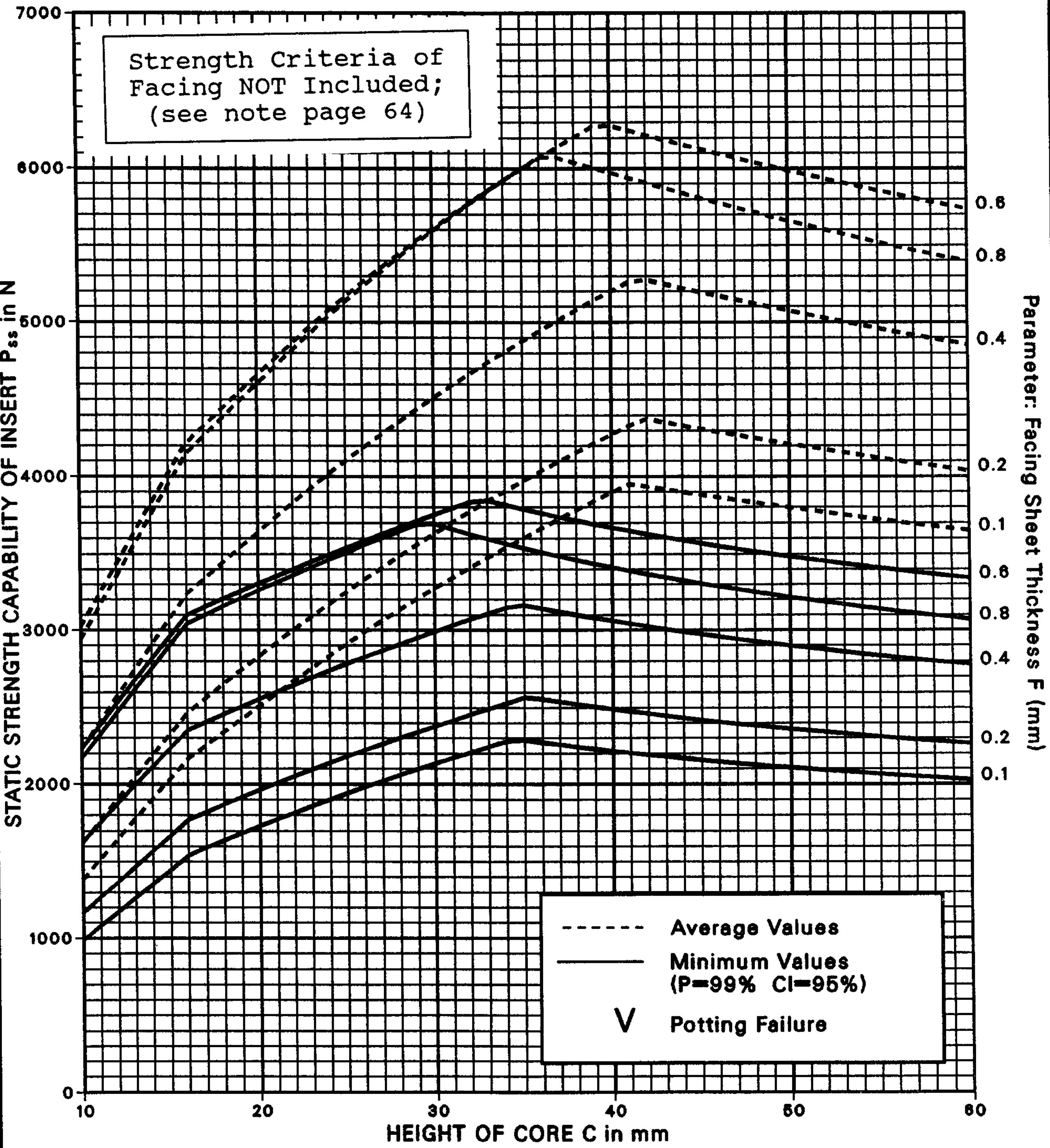


Insert Height h = 9 mm Facing Material AL 2024

Load : **Compression**

Insert Diameter: **11.0 mm**

Core : **HRP-3/16-5.5**

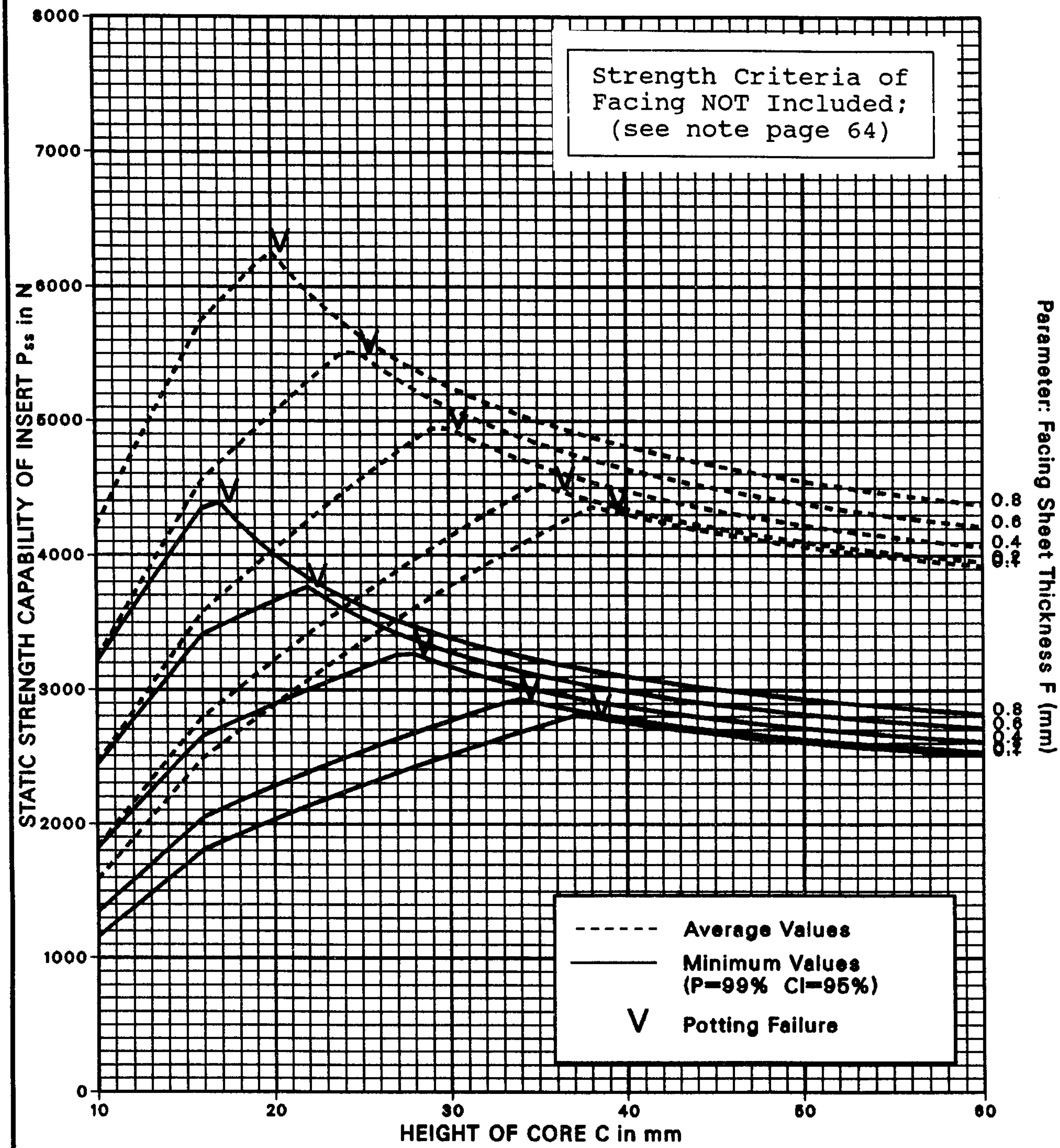


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Tension**

Insert Diameter: **14.0 mm**

Core : **HRP-3/16-5.5**

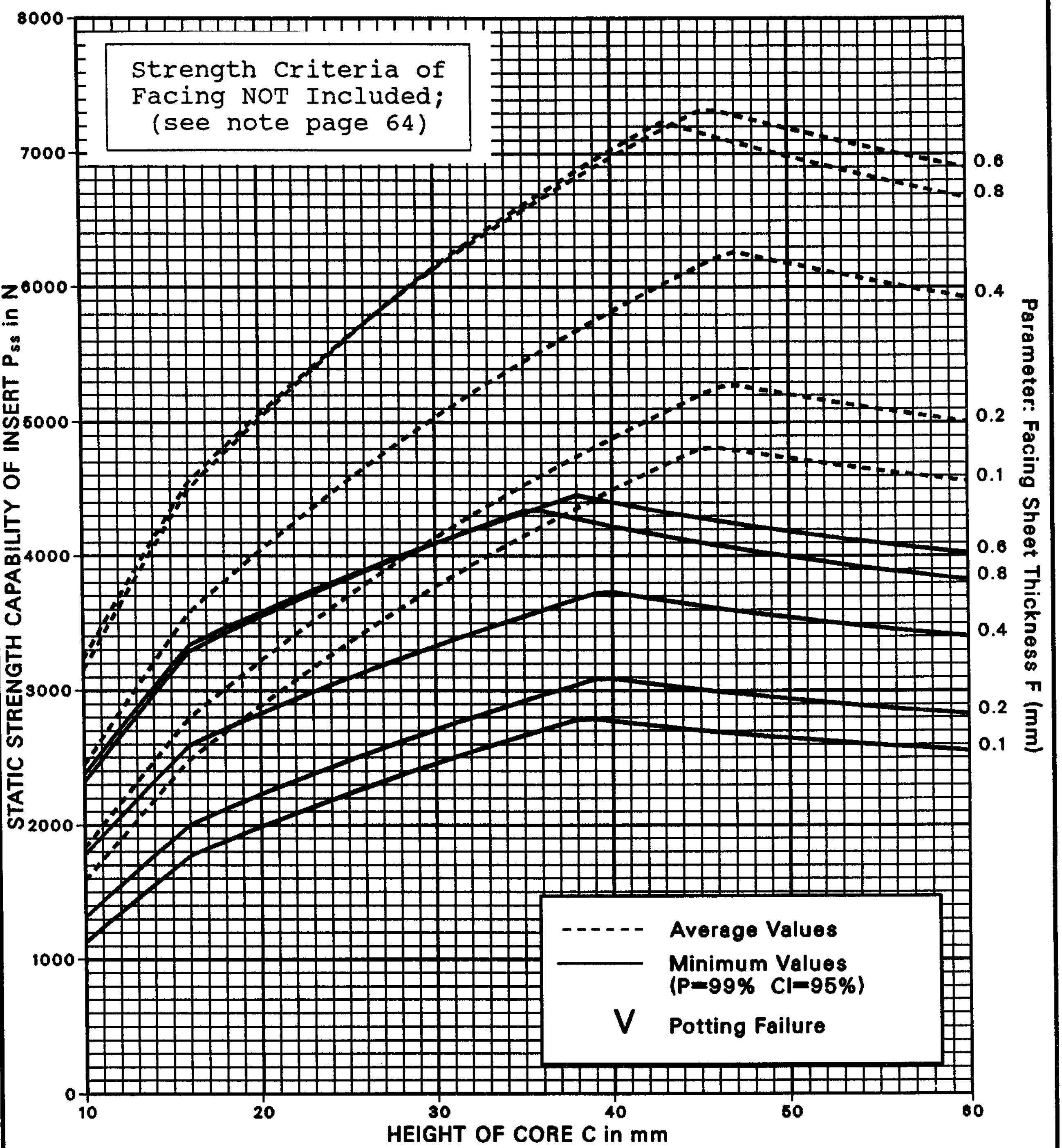


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Compression**

Insert Diameter: **14.0 mm**

Core : **HRP-3/16-5.5**



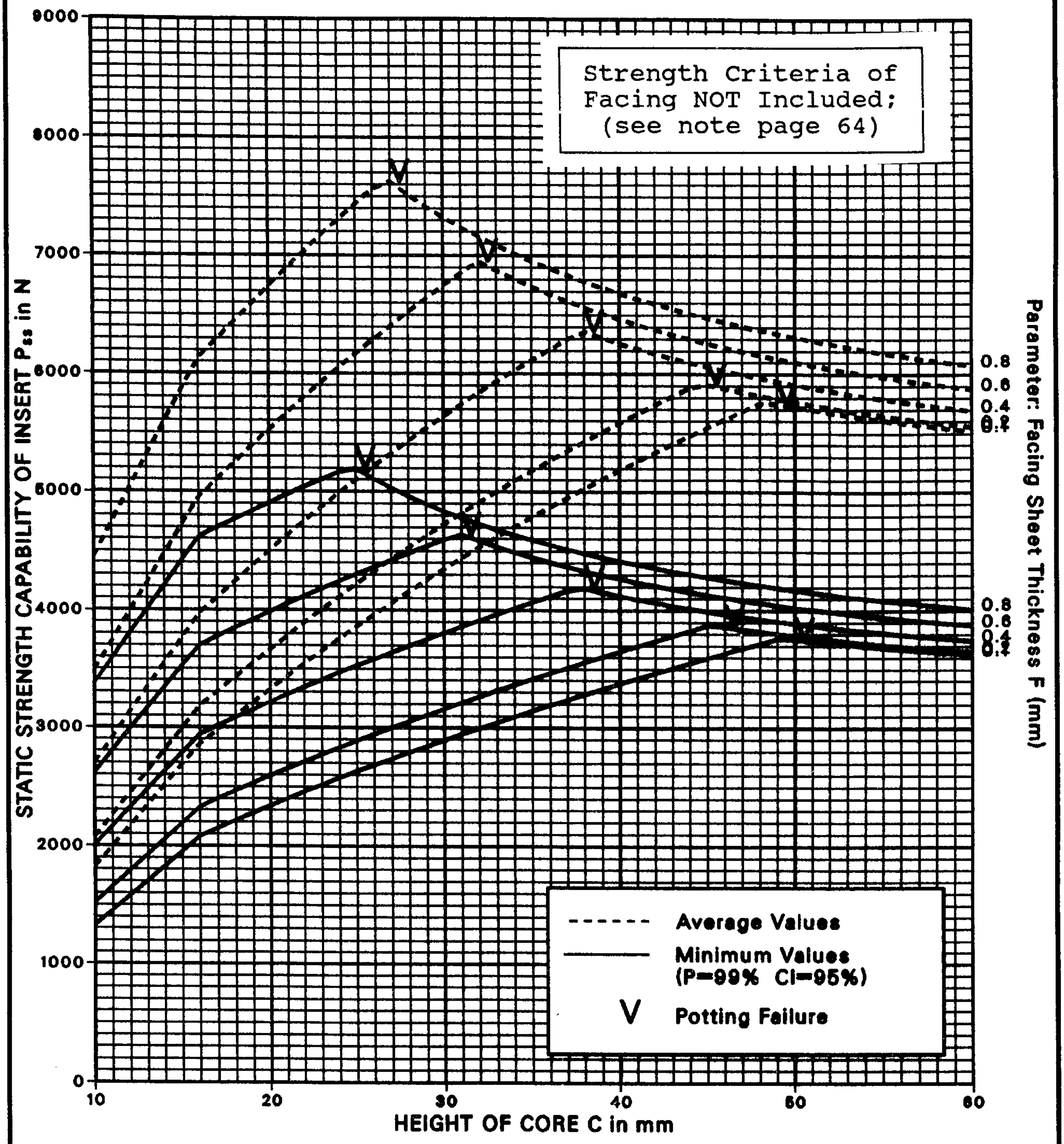
Insert Height h = 9 mm

Facing Material AL 2024

Load : **Tension**

Insert Diameter: **17.5 mm**

Core : **HRP-3/16-5.5**

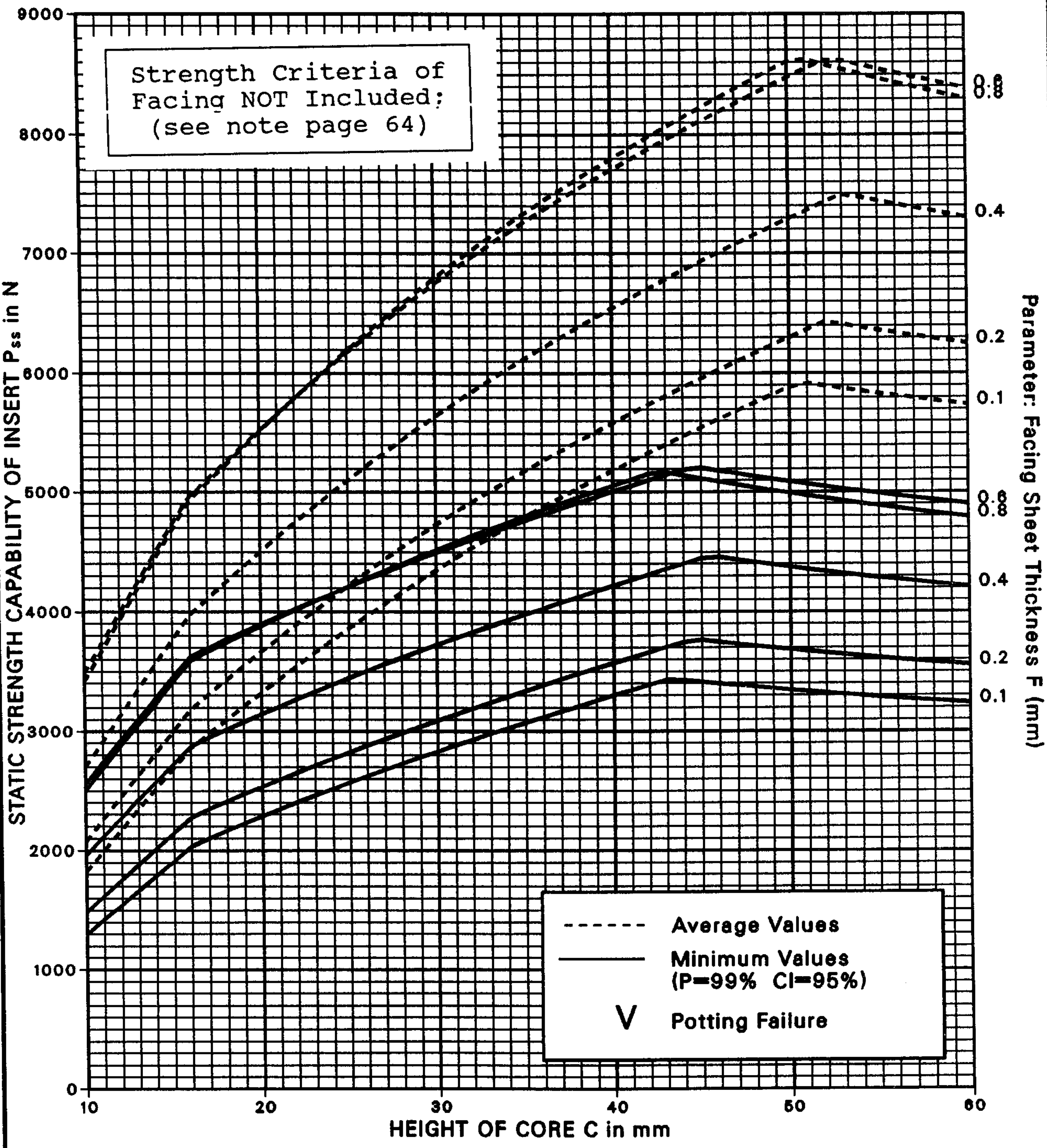


Insert Height h = 9 mm — Facing Material AL 2024

Load : Compression

Insert Diameter: 17.5 mm

Core : HRP-3/16-5.5

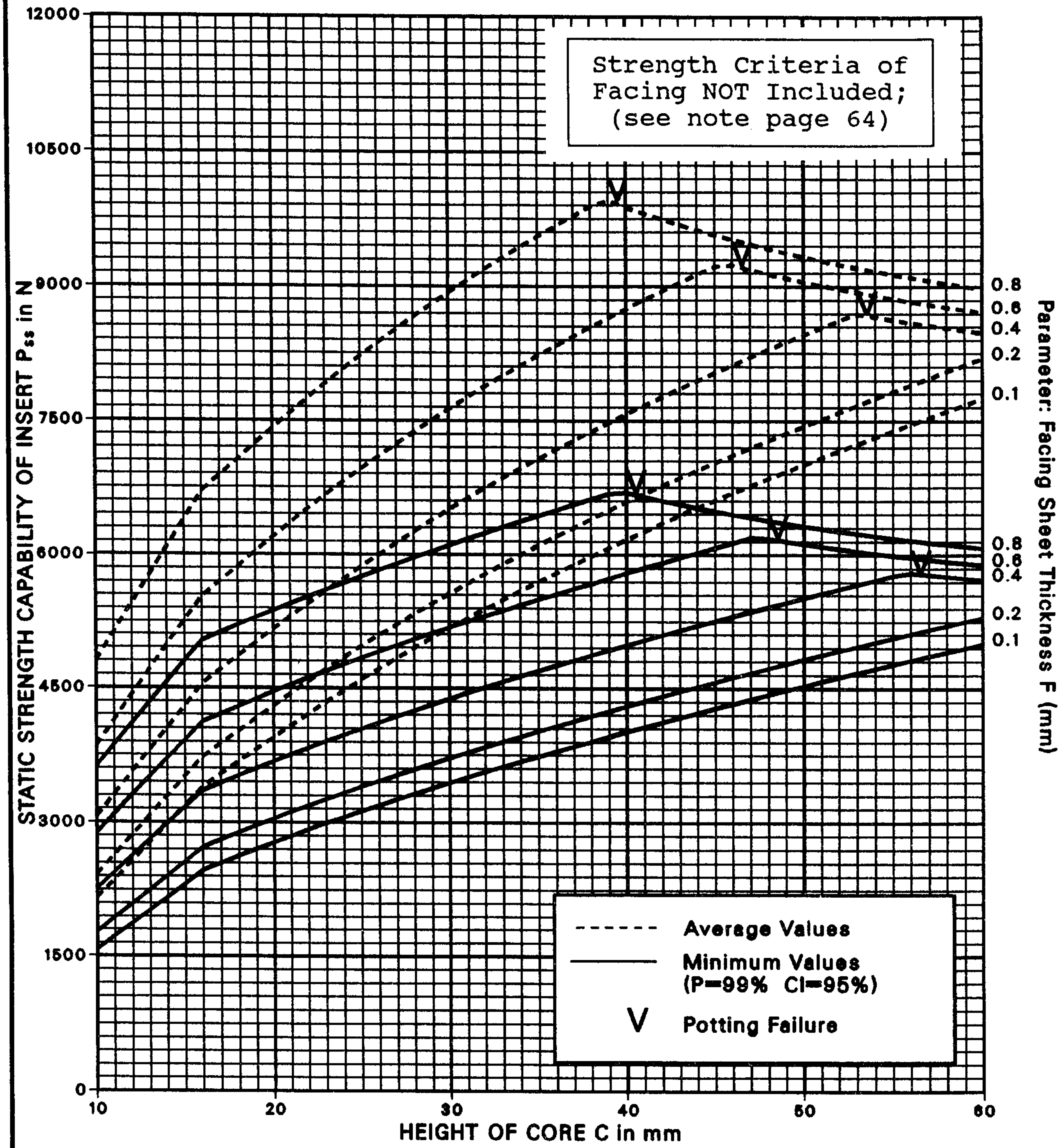


Insert Height h = 9 mm	Facing Material AL 2024

Load : **Tension**

Insert Diameter: **22.5 mm**

Core : **HRP-3/16-5.5**

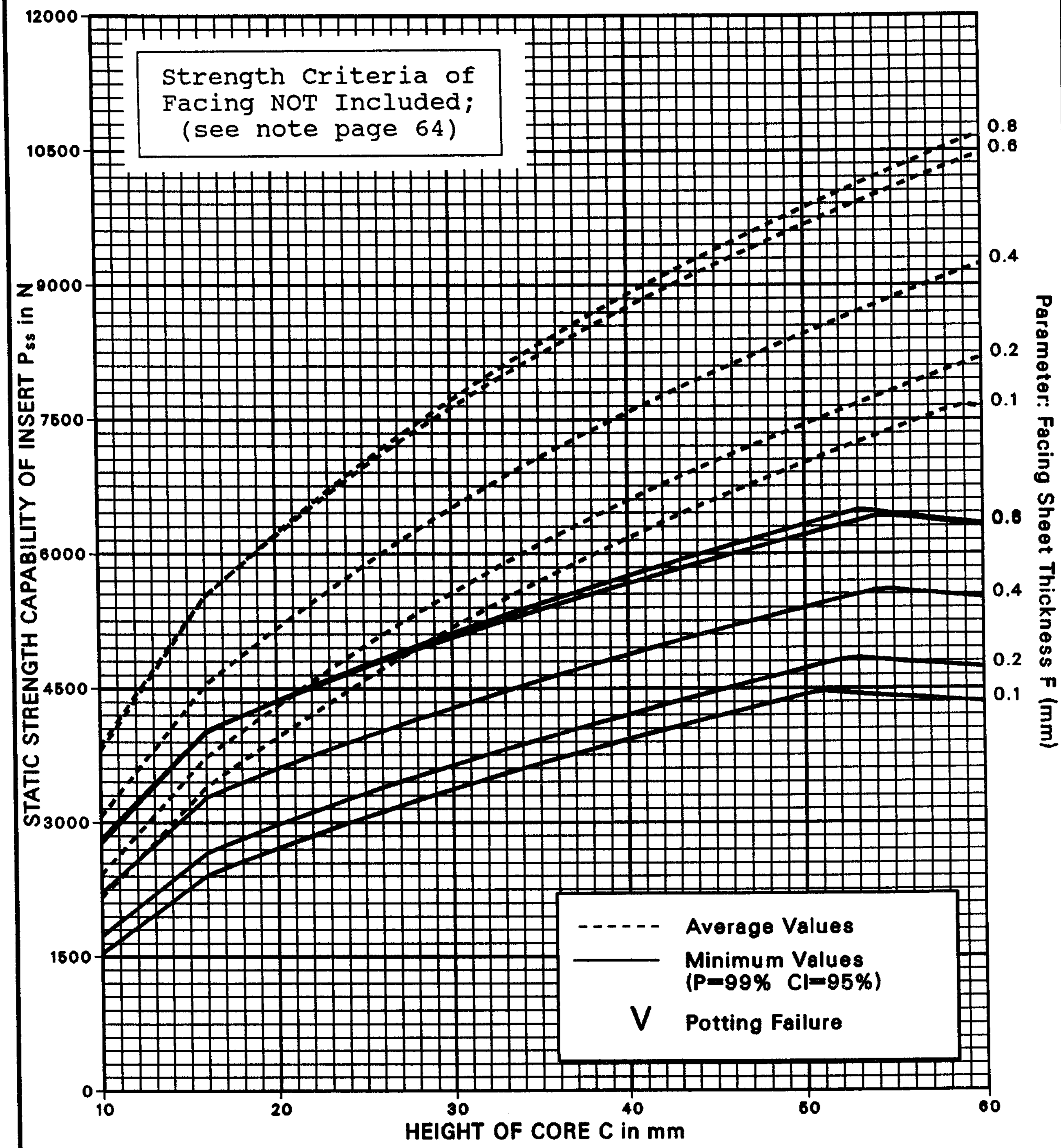


Insert Height h = 9 mm | Facing Material AL 2024

Load : **Compression**

Insert Diameter: **22.5 mm**

Core : **HRP-3/16-5.5**



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2.1.3 Shear (in-plane) Load

2.1.3.1 General

The shear or in plane load Q, applied to the insert is considered to act in the midplane of the upper facing sheet (see Fig. 2.1.2).

It is required that the diameter D of the foot of the attached part is at least as great as the typical potting diameter, i.e.

$$D \geq 2\ b_p \sim 2\ (b_i + 4\ \text{mm}) \qquad (2.1.4)$$

This is necessary in order to ensure sufficient clamping of the insert and to prevent the insert from being pushed under the upper facing sheet (Fig. 2.1.2).

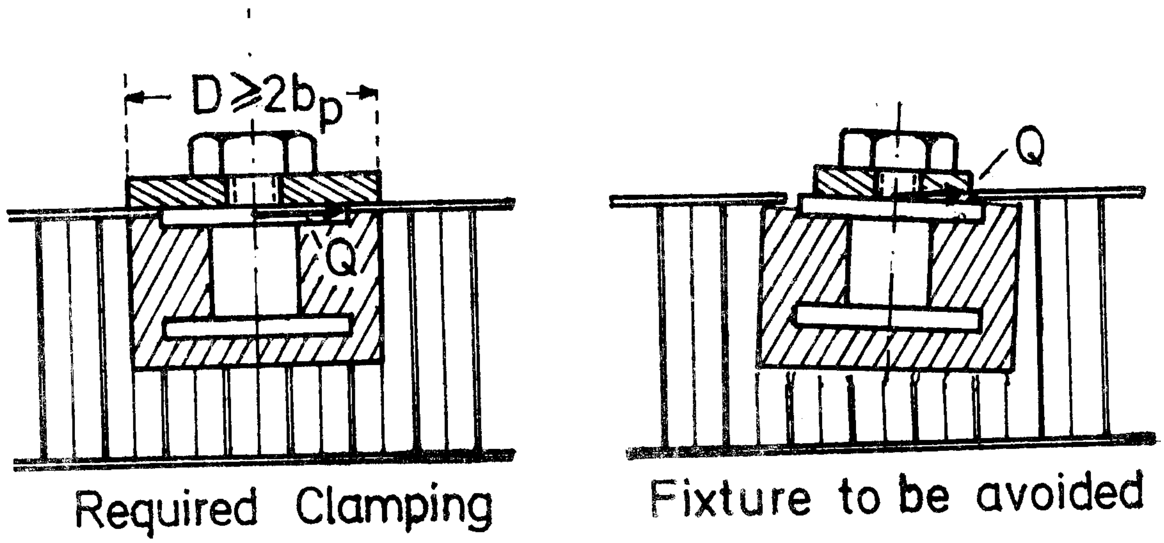

Fig. 2.1.2: Clamping Conditions for Shear (Q)-Loaded Inserts

Under these conditions the insert/sandwich combination fails in case of a metallic facing sheet by compressive buckling of the upper facing sheet around the socket of the attached part. Therefore, the capability of the shear-loaded insert is limited by the yield strength σ_{fy} of the facing sheet material.

In case of non-metallic facing sheets (e.g. CFRP), the failure mode of in-plane shear-loaded insert/sandwich combinations may differ from that of metallic facing.

The failure mode as well as the off-axis yield strength depend on

- o the used material
- o the number of layers
- o the stacking sequence

See also section 1.2.2.1.

Owing to the partial clamping of the core in the vicinity of the upper facing sheet, a small portion of the load is carried by the core. This part of the load, Q_c, depends on the stiffness of the core with respect to the load direction. Conservatively, only the stiffness of the weak W-direction (see Fig. 1.2.5) has to be taken into consideration.

This part of the load can be given by the semiempirical formula

$$Q_c = 8\, b_p^2\, \tau_{W\,crit} \qquad (2.1.5)$$

where $\tau_{W\,crit}$ = shear strength of core in W-direction.

The critical shear load is quasi-independent of the core height c.

2.1.3.2 Permissible Shear Load - Q_{SS}

The shear load to which the insert can be submitted is given by the semi-empirical formula

$$Q_{SS} = 8\, b_p^2\, \tau_{W\,crit} + 2\, f\, b_p\, \sigma_{fy} \qquad \text{for } b_p \le 11 \text{ mm} \qquad (2.1.6)$$

where

b_p = potting radius according to section 1.2.3.2.1 or Tab. 2.1.2.1/2

τ_{Wcrit} = shear strength of core in W-direction according to Tab. 1.2.7.1/2

σ_{fy} = yield strength of facings according to standards (section 1.2.2.2.4)

f = thickness of upper facing sheet

This formula is confined to $b_p \le 11$ mm owing to the difficulty of meeting the clamping requirement as shown in Fig. 2.1.2 for greater potting radii:

$b_p = 11$ mm has to be used in equ. (2.1.6) for $b_p \ge 11$ mm

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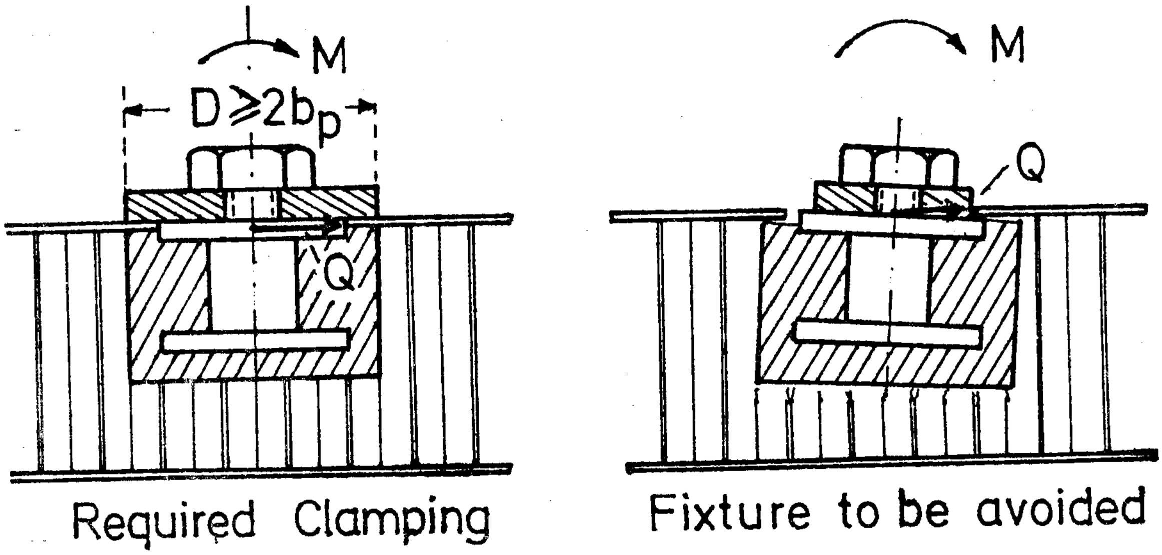
2.1.4 Bending Load

2.1.4.1 General

Generally one should avoid subjecting inserts to bending loads. Where this cannot be avoided (e.g. by using coupled inserts, which convert the load to tension/ compression) one has to ensure that, as in shear-loaded inserts, the diameter D of the foot of the attached part is at least as great as the potting diameter 2 b_p (see Fig. below and comments to Fig. 2.1.2.

The bending capability of inserts in non-metallic cores determined in this manner is considered an estimate possibly helpful for a preliminary design.



2.1.4.2 Permissible Bending Load M_{SS}

Under the conditions mentioned above, the bending load to which the insert can be subjected is given by the formula

$$M_{SS} = P_{SS\,c} \cdot b_i \qquad (2.1.7)$$

with $P_{SS\,c}$ = permissible compressive loads according to section 2.1.2.

b_i = radius of insert

2.1.5 Torsional Load

2.1.5.1 General

Like bending loads (para. 2.1.4), torsional loads on single inserts should be avoided by using coupled inserts. Where this is not possible, one must ensure that the diameter D of the foot of the attached part is at least as great as the potting diameter, i.e. $D \geq 2\,(b_i + 4\text{ mm})$ (Fig. 2.1.2).

2.1.5.2 Permissible Torsion Load T_{SS}

The most unfavourable case is a shear rupture of the cell walls enclosing the potting, without any load participation by other parts of the sandwich/ insert combination. The shear strength of these cell walls is that of the foil material, i.e.

$\tau_{o\ crit} = 180\ \text{N/mm}^2$ for 5052 H38

$\tau_{o\ crit} = 220\ \text{N/mm}^2$ for 5056 H38

The torsional load to which the single insert in a metallic core can at most be submitted is given by the formula

$$T_{SS} = 4\,\pi\,b_R^2\,t_o\,\tau_{o\ crit} \qquad (2.1.8)$$

where

b_R = real potting radius according to Tab. 2.1.2

t_o = foil thickness of the core according to Tab. 1.2.7.1

The permissible torsion load of inserts in non-metallic cores has to be determined by tests.

2.1.6 Load Combinations

2.1.6.1 Inclined Loading

The most common load combination is the inclined load F which is a combination of a normal load P (tensile or compressive) and a shear load Q (Fig. 2.1.3).

$P = F \sin \alpha$ = component in normal direction

$Q = F \cos \alpha$ = omponent in shear direction

F = applied inclined or angle load

α = angle between applied load F and sandwich plane

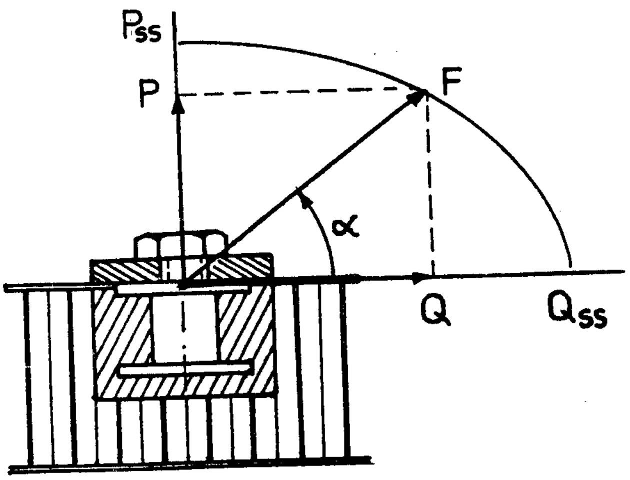


Fig. 2.1.3: Insert Submitted to an Inclined Load

With known components Q and P, it has to be shown that

$$\left(\frac{P}{P_{SS}}\right)^2 + \left(\frac{Q}{Q_{SS}}\right)^2 \leq 1 \qquad (2.1.9)$$

with given angle of resultant, the allowable F_{SS} becomes

$$|F_{SS}| = \frac{P_{SS} \quad Q_{SS}}{\sqrt{P_{SS}^2 \cdot \cos^2\alpha + Q_{SS}^2 \cdot \sin^2\alpha}} \qquad (2.1.10)$$

with P_{SS} = permissible tensile or compressive load according to section 2.1.1 or 2.1.2

Q_{SS} = permissible shear load according to section 2.1.3, Equ. 2.1.6.

2.1.6.2 General Load Combination

An insert submitted simultaneously to the following loads

P = normal load (tensile or compressive)
Q = shear (in-plane) load
M = bending moment
T = torsional moment

has to meet the following requirement

$$\left(\frac{P}{P_{SS}}\right)^2 + \left(\frac{Q}{Q_{SS}}\right)^2 + \left(\frac{M}{M_{SS}}\right)^2 + \left(\frac{T}{T_{SS}}\right)^2 \leq 1 \qquad (2.1.11)$$

with the permissible loads

P_{SS} according to section 2.1.1 or 2.1.2
Q_{SS} according to section 2.1.3, Equ. 2.1.6
M_{SS} according to section 2.1.4, Equ. 2.1.7
T_{SS} according to section 2.1.5, Equ. 2.1.8.

Bending and torsion need to be covered by adequate design (e.g. large foot, groups of inserts, etc.)

2.1.7 Thermal Influences

2.1.7.1 General

Thermal conditions may lead to a reduction in insert capability. Figure 2.1.4 shows this reduction caused by three different types of thermal conditions

a) Mechanical loading in a thermal environment

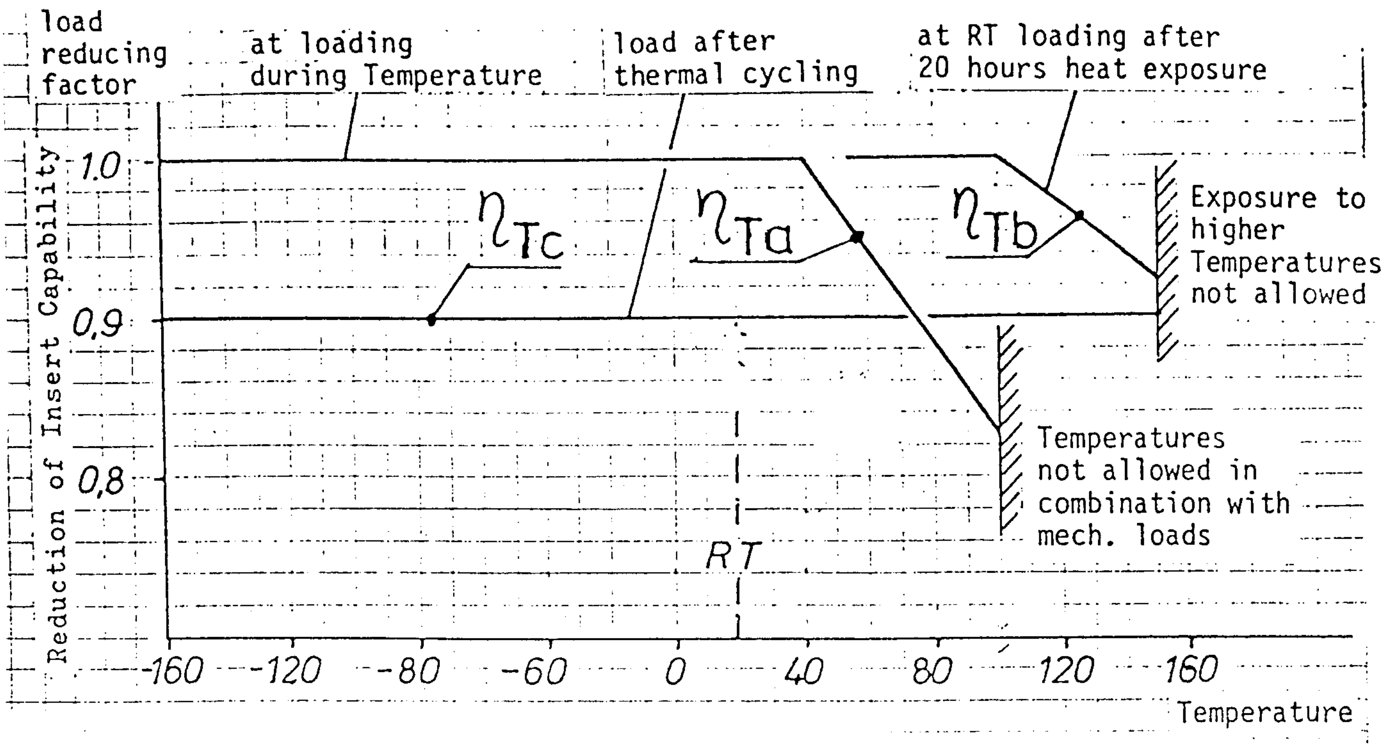
- For temperatures below 40 °C, down to temperatures of -160 °C, the insert capability is not affected. Tests have shown that the insert capability even increases with decreasing temperature.
- For temperatures above 40 °C the insert capability decreases.
- Temperatures over 100 °C should not occur simultaneously with mechanical loading of the insert, owing to the reduction of the tensile strength of the potting resin (Fig. 2.1.4).

b) Mechanical loading after submission to a thermal environment

The insert capability is only reduced after submission to temperatures above 100 °C.

c) Mechanical loading after thermal cycling

Thermal cycling between +120 °C and -160 °C causes a capacity reduction down to 90 % of the unaffected insert/sandwich system.



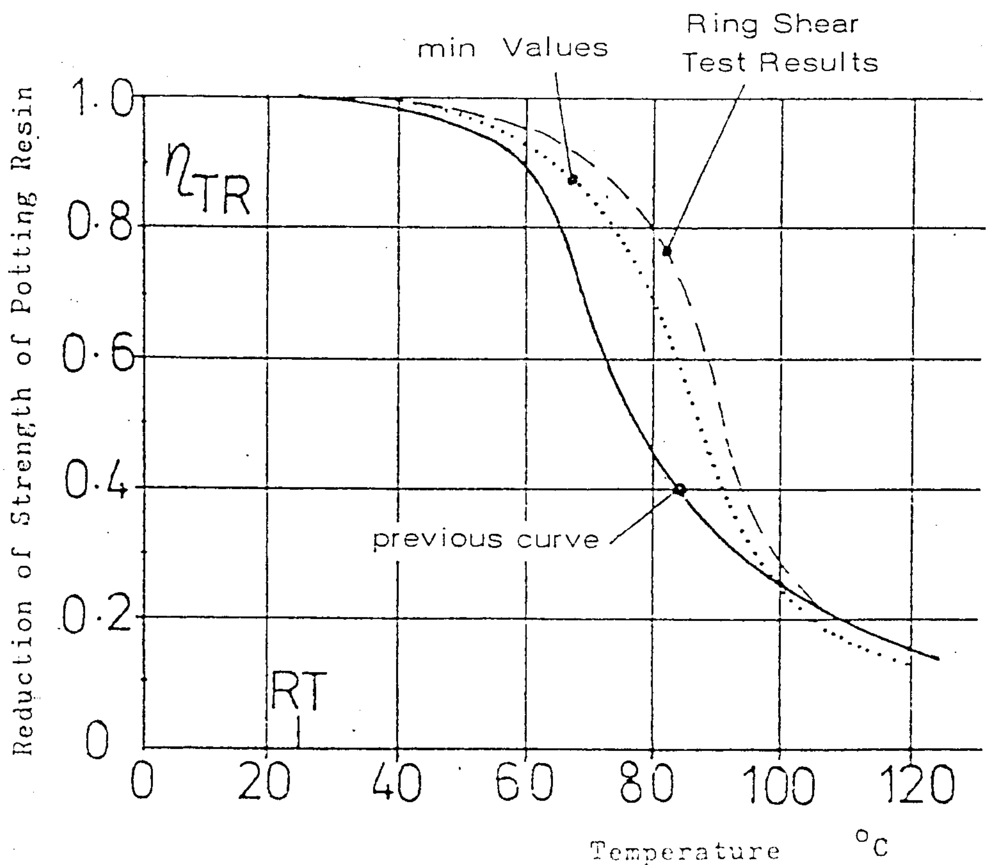


Fig. 2.1.4: Reduction of Insert Capability and of Strength of Potting Resin due to Thermal Environment

2.1.7.2 Reduction of Permissible Load Resulting from Thermal Environment

The thermal environment affects primarily

- o the permissible tensile load according to section 2.1.1.2
- o the permissible compressive load according to section 2.1.2.2
- o the permissible bending load according to section 2.1.4.1

The permissible shear and torsional loads are not affected by the thermal environment.

The reduction of the permissible loads mentioned above has to be accounted for by means of a coefficient of thermal degradation according to the formula

$$P_{SS\,T} = \eta_T \, P_{SS} \qquad (2.1.12)$$

where

$P_{SS\,T}$ = permissible load reduced by thermal environment

P_{SS} = permissible load without thermal influence, according to section 2.1.1.2, 2.1.2.2, 2.1.4.2

η_T = coefficient of thermal degradation according to the following sections and to Fig. 2.1.4.

a) Mechanical loading in a thermal environment

$\eta_T = \eta_{Ta}$ as far as the permissible loads are limited by the core properties (Fig. 2.1.5 and Fig. 2.1.4).

$\eta_T = \eta_{TR}$ as far as the permissible loads are limited by the resin properties (Fig. 2.1.5 and Fig. 2.1.4).

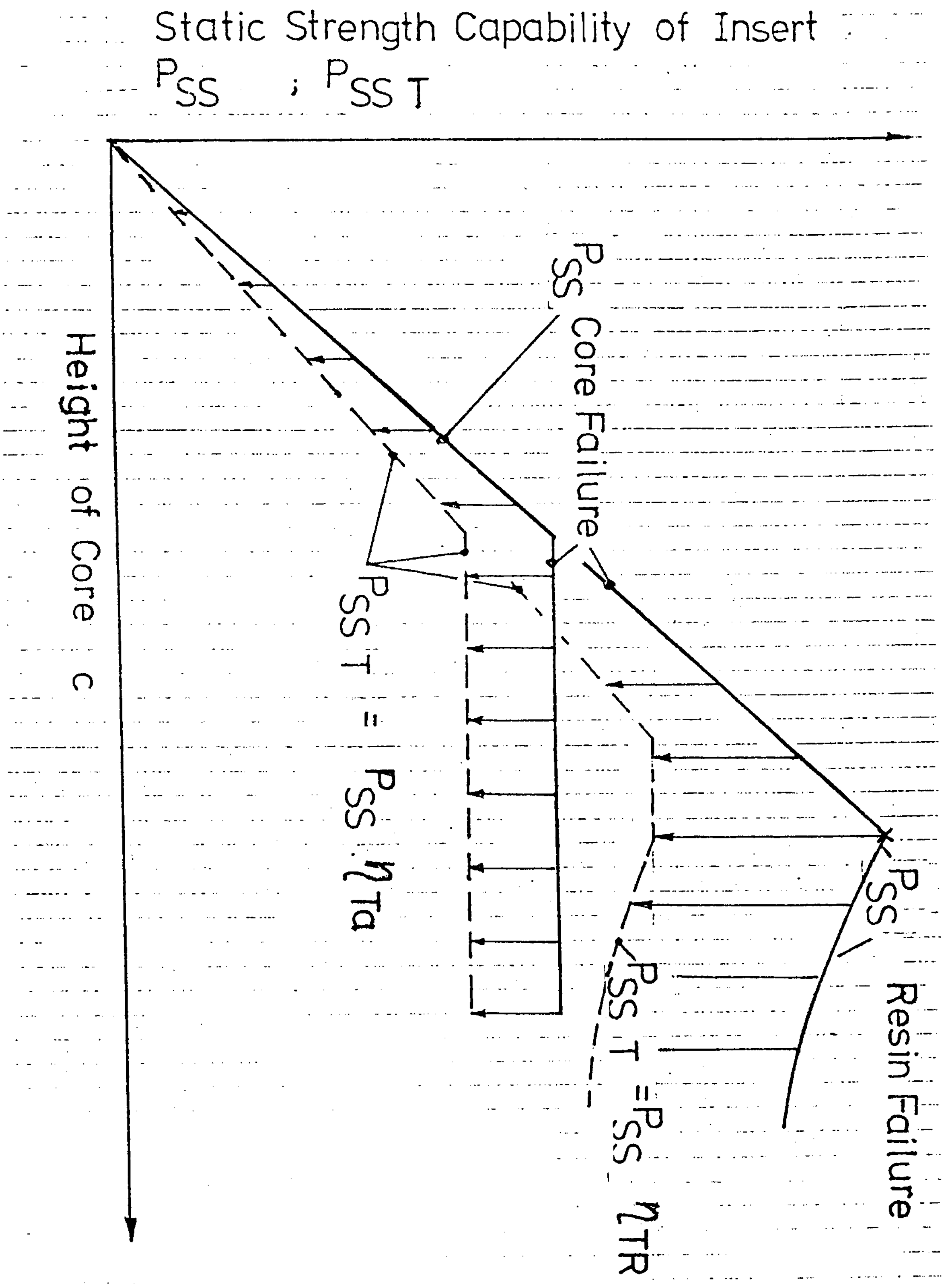


Fig. 2.1.5: Capability Reduction for Inserts under Elevated Temperature

b) Mechanical loading after submission to a thermal environment

$$\eta_T = \eta_{Tb}$$

c) Mechanical loading after thermal cycling

$$\eta_T = \eta_{Tc}$$

η_{Tc} is valid for 100 cycles in a range between -160 °C and +150 °C.

2.1.8 Other Load Conditions

Influences of secondary nature are

- o humidity (under atmospheric environmental conditions)
- o vacuum (under space environmental conditions)
- o radiation

Each of these influences is able to degrade the potting mass and consequently decrease the insert capabilities to a certain extent.

On the other hand, the potting mass is well protected by the surrounding aluminium structure, which means that deterioration of the potting mass will take place only under extreme conditions.

When such conditions are anticipated, particular attention should be paid to the selection of a potting mass that is highly resistent to them.

2.2 Static Strength Capability of Insert Groups

2.2.1 Mutual Interference of Two Inserts Loaded in the Same Direction

If two adjacent inserts are simultaneously loaded in the same direction, the static strength capability of each insert is reduced by the stress field of the other insert according to the formula

$$P^{*}_{SS1} = \eta_{IS1} \, P_{SS1} \qquad (2.2.1)$$

where

P^{*}_{SS1} = reduced capability of insert 1, due to insert 2

P_{SS1} = initial capability of insert 1, without influence of insert 2

If the distance between the insert exceeds the value

$$a \leq 5 \, (b_{p_1} + b_{p_2}) \qquad (2.2.2)$$

η_{IS1} = interference coefficient of insert 1, when simultaneously loaded in the same direction as insert 2

$$\eta_{ISI} = \frac{b_{p_1}/b_{p_2}}{1 + b_{p_1}/b_{p_2}} \left(1 + \frac{a}{5b_{p_1}} \times \frac{1}{(1 + b_{p_1}/b_{p_2})}\right) \qquad (2.2.3)$$

where

b_{p_1} = potting radius for insert 1

b_{p_2} = potting radius for insert 2

a = heart-to-heart distance between inserts

Fig. 2.2.1

If the distance between the inserts exceeds the value

$$a > 5\,(b_{p_1} + b_{p_2})$$

the mutual influence of both inserts is negligible, i.e.

$$\eta_{IS1} = \eta_{IS2} = 1 \qquad \text{for } a > 5\,(b_{p_1} + b_{p_2}) \tag{2.2.4}$$

where η_{IS2} = interference coefficient of insert 2, when simultaneously loaded in the same direction as insert 1

$$= \frac{(b_{p_1}/b_{p_2})^{-1}}{1 + (b_{p_1}/b_{p_2})^{-1}} \left(1 + \frac{a}{5b_{p_1}} \times \frac{b_{p_1}/b_{p_2}}{[1 + (b_{p_1}/b_{p_2})^{-1}]}\right) \tag{2.2.5}$$

Insert 2's reduction of the capability of insert 1, given by η_{IS1}, is only fully effective if insert 2 is itself loaded up to its own capability:

$$P^*_{SS2} = \eta_{IS2}\, P_{SS2} \tag{2.2.6}$$

where P^*_{SS2} = reduced capability of insert 2, due to insert 1

If insert 2 is submitted to an actual load P_2 which is lower than the reduced load capability P^*_{SS2} of this insert, the reducing influence on insert 1 is smaller. The load capability reduction of insert 1 is then given by

$$\eta'_{IS1} = 1 - (1 - \eta_{IS1})\, P_2/P^*_{SS2} \tag{2.2.7}$$

This case may be relevant if both inserts are not simultaneously loaded up to their respective, reduced capabilities P^*_{SS1} and P^*_{SS2}.

η_{IS1} and η_{IS2} have been plotted as a function of the relative insert distance a/b_{p_1} in Fig. 2.2.1; the parameter is the ratio of potting radii b_{p_1}/b_{p_2}.

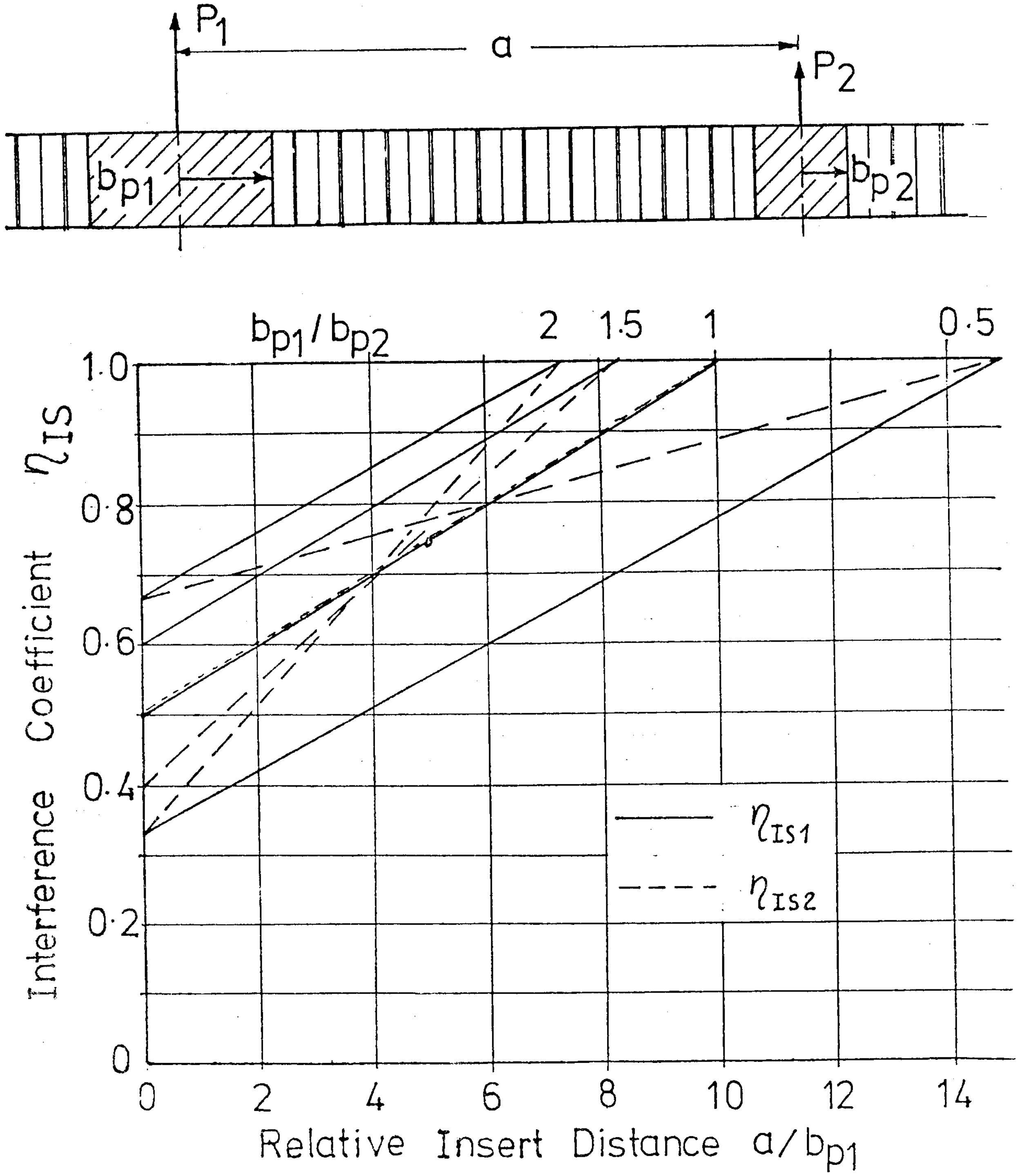


Fig. 2.2.1: Capability Reduction of 2 Adjacent Inserts, Loaded in the Same Direction

2.2.2 Mutual Interference of Two Inserts Loaded in Opposite Directions

If two adjacent inserts are simultaneously loaded in contrary directions ($P_1 = -P_2$), the static strength capability of each insert is only slightly reduced by the stress field of the other insert.

For design purposes, the reduced capability of two inserts loaded in contrary directions is given by

$$P^*_{SS} = P_{ss} \cdot \eta_{IC} \tag{2.2.8}$$

where P^*_{SS} = capability of one insert reduced by the second insert

P_{SS} = initial capability of a single insert

η_{IC} = interference coefficient for contrary loading

$$\left.\begin{aligned} \eta_{IC} &= 0.9 \text{ for } a \leq 5\,(b_{p_1} + b_{p_2}) \\ \eta_{IC} &= 1.0 \text{ for } a > 5\,(b_{p_1} + b_{p_2}) \end{aligned}\right\} \quad \text{for definition of geometric configuration see Fig. 2.2.1} \tag{2.2.9}$$

2.2.3 Mutual Interference of a Larger Number of Inserts

2.2.3.1 Series of Inserts Loaded in the Same Direction (Fig. 2.2.2)

The first and last inserts of a series are primarily influenced by only one adjacent insert. Its reduced capability can be determined according to section 2.2.1:

$$P^*_{SS1} = P_{SS1}\,\eta_{IS1} \qquad (2.2.1)$$

where

P^*_{SS1} = capability of first or last insert reduced by second or last but one insert

P_{SS1} = initial capability of first or last insert

η_{IS1} = interference coefficient of first or last insert related to the second or last but one insert, according to equ. (2.2.2)

The intermediate (i) inserts are primarily influenced by the insert immediately to their left (l) and right (r). Their reduced capability is

$$P^*_{SSi} = P_{SSi}\,(\eta_{ISl} + \eta_{ISr} - 1) \qquad (2.2.10)$$

where

P^*_{SSi} = capability of intermediate insert influenced by both adjacent inserts

P_{SSi} = initial capability of intermediate insert

η_{ISl} = interference coefficient of intermediate insert related to left insert, according to equ. (2.2.2) with b_{p_1} = potting radius of intermediate insert, b_{p_2} = potting radius of left insert and $a = a_l$ = distance between the centres of intermediate and left insert.

η_{ISr} = interference coefficient of intermediate insert related to the right insert, according to equ. (2.2.2) with b_{p_1} = potting radius of intermediate insert, b_{p_2} = potting radius of right insert and $a = a_r$ = distance between the centres of intermediate and right insert.

<u>Example</u> Insert Capability for the following configuration:

- series of 5 equal inserts
- equal potting radius b_p for all inserts
- equal insert distance $a = 6\ b_p$

According to Fig. 2.2.1, the interference coefficient corresponding to $b_{p_1}/b_{p_2} = 1$ and $a/b_{p_1} = 6$ is identical for all inserts:

$$\eta_{IS1} = \eta_{ISl} = \eta_{ISr} = 0.8$$

The static strength capabilities are then

$$P^*_{SS1} = 0.8\ P_{SS} \text{ for insert 1 and 5}$$

$$P^*_{SSi} = P_{SS}\ (0.8 + 0.8 - 1)$$
$$= 0.6\ P_{SS} \text{ for insert 2, 3 and 4}$$

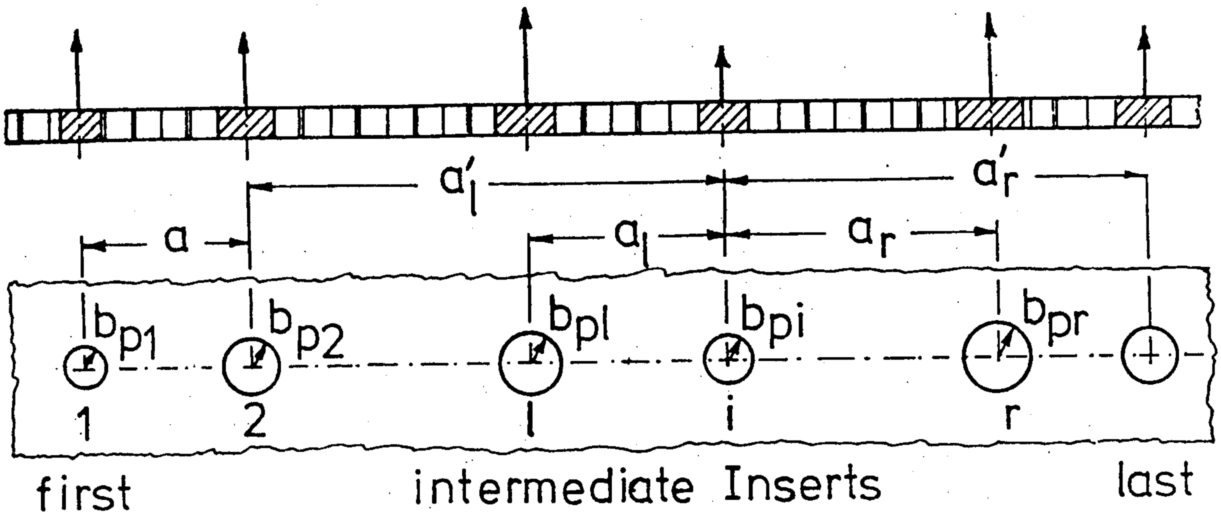
where

P_{SS} = initial static strength capability of the used insert.

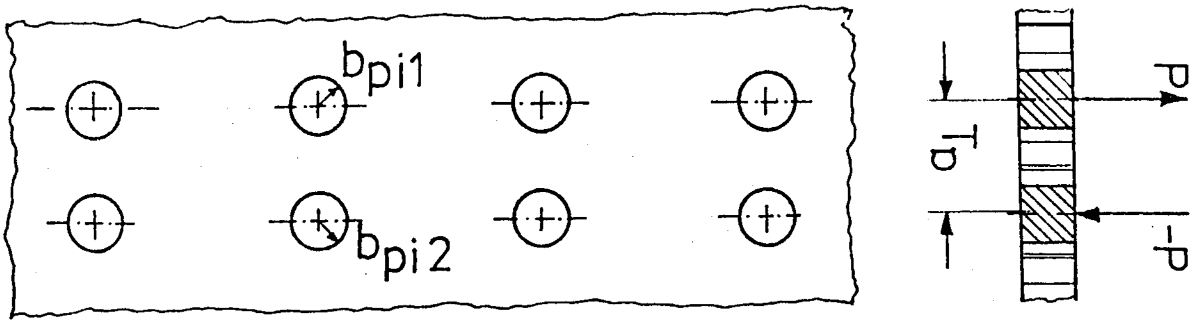
<u>Validity</u> The formulas given above are considered valid if the distance a' between the insert and its vicinity is large enough, i.e.

$$a' \geq 5\ (b_{pi} + b_{pi\pm2}) \qquad (2.2.11)$$

otherwise the next-but-one insert also influences the considered insert. In this case the total capability of the series ΣP^*_{SS}, determined by the mentioned formulas, remains valid, while the distribution of the load over the inserts is incorrect.



Series of Inserts Loaded in Same Direction



Two Contrarily Loaded Series of Inserts

Fig. 2.2.2: Mutual Interference of Inserts in Series

2.2.3.2 Two Series of Inserts Loaded in Opposite Directions

The loading configuration is shown in Fig. 2.2.2.

The reduced load capability of each insert can be estimated according to:

- o Equ. (2.2.1) and Equ. (2.2.8) for the first and the last insert:

$$P^*_{SS1} = P_{SS1}\ \eta_{IS1}\ \eta_{IC} \qquad (2.2.1.a)$$

- o Equ. (2.2.10) and Equ. (2.2.8) for the intermediate inserts

$$P^*_{SSi} = P_{SSi}\ (\eta_{ISl} + \eta_{ISr} - 1)\ \eta_{IC} \qquad (2.2.10a)$$

where (see Fig. 2.2.2):

$$\eta_{IC} = \begin{cases} 0.9 \text{ for } a \leq 5\ (b_{pi_1} + b_{pi_2}) \\ 1.0 \text{ for } a > 5\ (b_{pi_1} + b_{pi_2}) \end{cases} \qquad (2.2.9a)$$

a = distance between insert series

b_{pi_1} = potting radius for insert No. i of first series

b_{pi_2} = potting radius for insert No. i of second series

2.2.3.3 Insert Groups Loaded in the Same Direction

Greater loads may be applied via brackets to a number of inserts, i.e. in a group of 3, 4, 5 or 6 inserts (Fig. 2.2.3). For equal and equidistant inserts the load capability of each insert of the group is

$$P^*_{SS} = \eta_G\ P_{SS} \qquad (2.2.12)$$

where

P^*_{SS} = reduced capability of insert

P_{SS} = initial capability of single insert

η_G = interference coefficient for a group of equidistant inserts, depending on the number of inserts:

$$\eta_G = 2\left(\frac{n-1}{n}\,\eta_{IS} + \frac{1}{n} - 0.5\right) \qquad (2.2.13)$$

where

n = number of inserts in the group

η_{IS} = interference coefficient for 2 inserts loaded in the same direction, according to Equ. (2.2.2), with b_{pi} = $b_{p_1} = b_p$ i.e. $b_{p_1}/b_{p_2} = 1$

$$= 1/2\,(1 + a/10\,b_p) \qquad (2.2.14)$$

Equ. (2.2.13) satisfies the boundary values

η_G = 1 for $a/b_p = 10$ or $\eta_{IS} = 1$
(no further mutual interference)

η_G = $1/n$ for $a/b_p = 0$ or $\eta_{IS} = 0.5$
(n inserts concentrated in 1 insert)

Equ. (2.2.13) and (2.2.14) are only valid for $a \leq 10\,b_p$. For greater insert distance:

$$\eta_G = \eta_{IS} = 1 \quad \text{for } a > 10\,b_p \qquad (2.2.15)$$

Equ. 2.2.13 and 2.2.14 are plotted in Fig. 2.2.3.

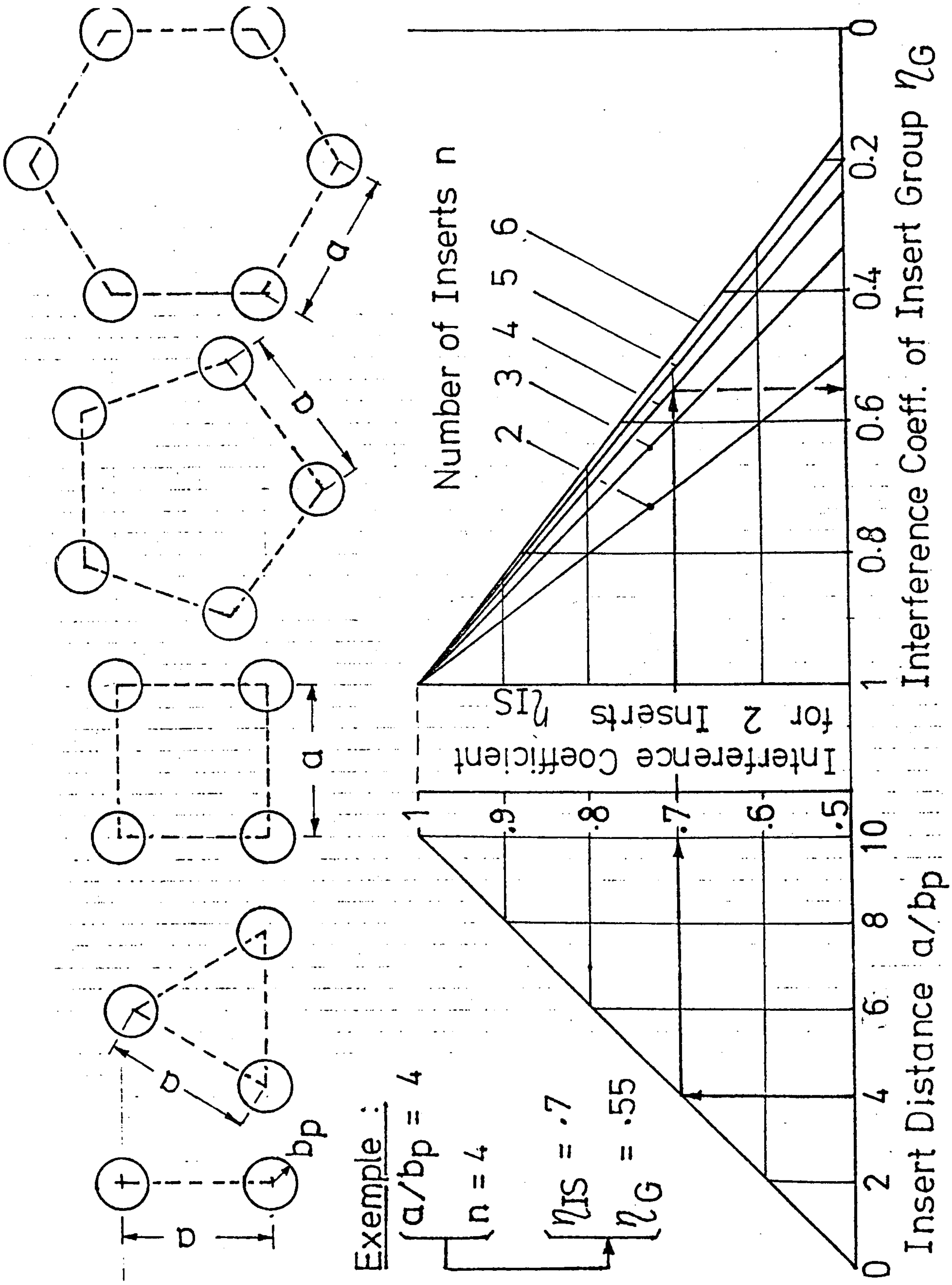


Fig. 2.2.3: Interference in a Group of Equal and Equidistant Inserts

2.3 Edge Influence on Static Strength Capability of Inserts

2.3.1 Influence of Edge Distance on Out-of-Plane Loaded Inserts

The reduced load carrying capability of inserts located close to a free panel edge, may be expressed by

$$P^*_{SS} = P_{SS}\, \eta_{EN} \qquad (2.3.1)$$

where

P^*_{SS} = insert capability under normal load, reduced by edge influence

P_{SS} = initial capability of insert according to section 2.2.1 and 2.2.2

η_{EN} = edge coefficient for normally loaded inserts

$$\begin{aligned} \eta_{EN} &= 0.55 \sqrt{e/b_p} - 0.05\, e/b_p && \text{for } e \leq 5\, b_p \\ \eta_{EN} &= 1 && \text{for } e > 5\, b_p \end{aligned} \qquad (2.3.2)$$

where

e = distance between insert centre and panel edge

b_p = potting radius of insert.

An edge distance smaller than b_p ($e < b_p$) is not allowed.

η_{EN} is plotted in Fig. 2.3.1.

2.3.2 Influence of Edge Distance on Inserts Under Shear Loading

The reduced load carrying capability of inserts under shear loading which are located close to a free panel edge, may be expressed by

$$Q^*_{SS} = Q_{SS}\, \eta_{EQ} \qquad (2.3.3)$$

where

Q^*_{SS} = shear-load capability of the insert, reduced due to the vicinity to the panel edge

Q_{SS} = initial shear load capability of insert according to section 2.1.3

η_{EQ} = edge coefficient for shear loaded inserts

In case of metallic facings:

$$\eta_{EQ} = 0.66\sqrt{e/b_p} - 0.06\, e/b_p \qquad \text{for } e \leq 3\, b_p$$
$$\eta_{EQ} = 1 \qquad \text{for } e > 3\, b_p \qquad (2.3.4)$$

An edge distance $e < b_p$ is not allowed.

η_{EQ} is plotted as a function of the relative edge distance e/b_p in Fig. 2.3.1.

In case of non-metallic facings tests are considered necessary.

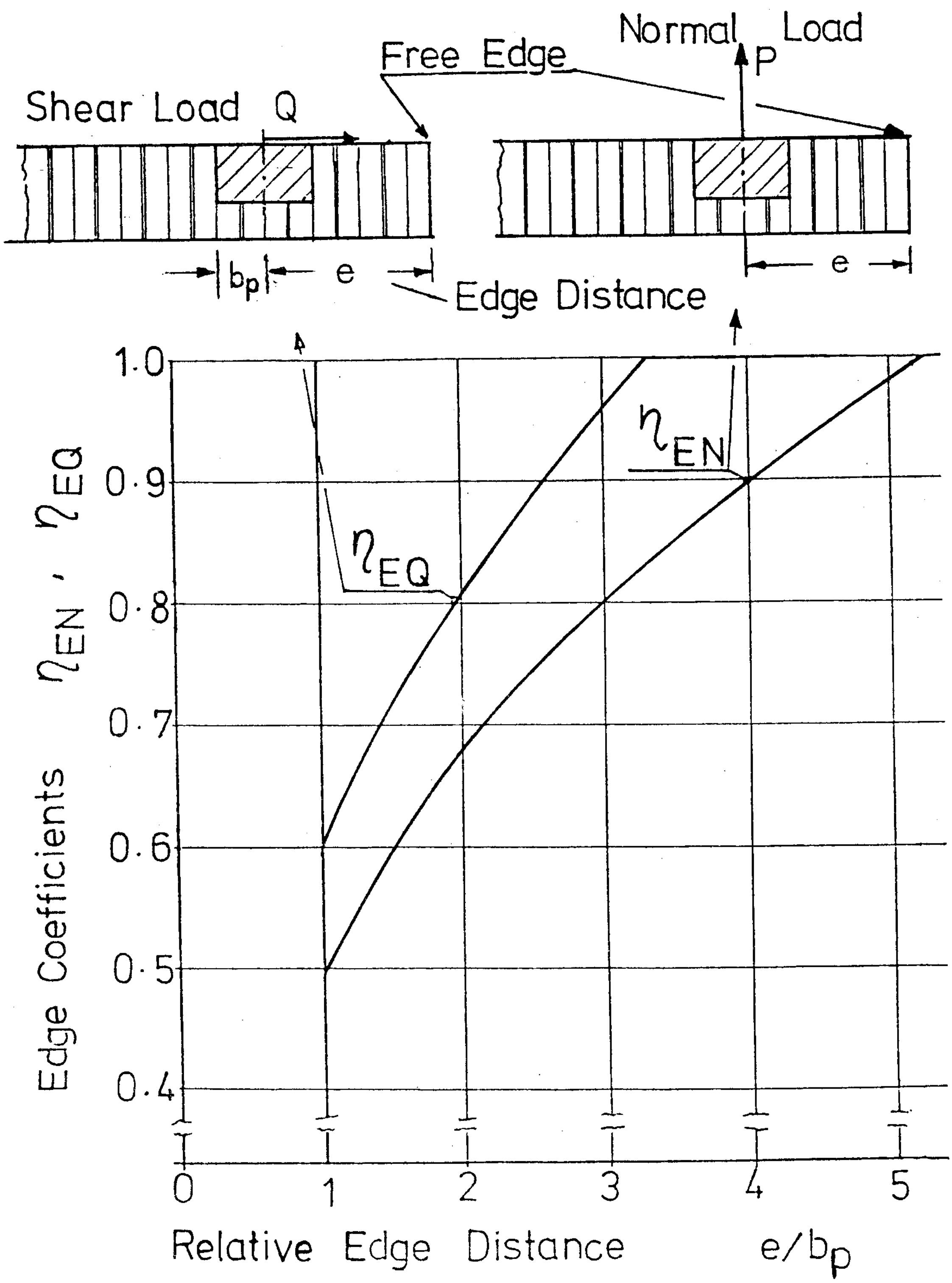


Fig. 2.3.1: Influence of Edge Distance on the Static Strength Capability of Inserts

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2.4 Insert Fatigue Life

The load-carrying capability of all components of a potted insert system (core, potting, facing insert and bolt) may be degradecd by repeated loading with increasing life. The failure of the insert element itself is not experienced provided an adequate fillet radius of lower flange connection is foreseen as maintained in most standards. Failures of the facings were never experienced with inserts in spacecraft panel design, the recommendation concerning the dimension of the bracket foot may be relevant here; see section 1.3.4. Bolts in inserts are not covered here; they should be designed in accordance to standard procedures.

The remaining components relevant to degradation under operational loads are

- o the honeycomb core
- o the potting.

In Ref. [3] it was shown that the correctly potted body is not subject to fatigue degradation if the surface treatment of the inner flange allows for a good adhesive connection with the resin; see recommendation, section 1.2.1.4. The strength of the potting body under operational condition is, however, influenced by elevated temperatures, see section 2.1.7.

The honeycomb core is significantly stressed by loads normal to plane of the facing. Cycling bending or torsion of the inserts need to be excluded by design (sufficient long bracket foot and/or insert groups). The fatigue damage in the core accumulated under repeated loads normal to plane is dependent upon three major variables:

- o the local shear stress occurring (potting dimensions, height of core, stress concentrations)

- o the stress sequence applied (mean stress, alternating stress, number of cycles) o the material resistance with respect to fatigue.

The different aspects are considered in the following subsections.

2.4.1 Local Stress by Loads Normal to Plane

The core shear stress around a potted insert is determined by the mathematical model reported in Appendix A. It is not necessary for the designer to solve the complicated equations, as the plots given in section 2.1.2.2 for each individual insert configuration contain implicitly the load/core stress τ_c information. The ultimate tensile capabilities P_{SS} given in the monotonically increasing area on the left are based upon $\tau_{c\ crit\ min}$ values as presented in the tenth column of Table 1.2.7.1/2.

In accordance to the model (Appendix A) the circular shear stress in core becomes:

$$\tau_c = \frac{C^* \cdot Kr_{max}}{2\ \pi\ b_p \cdot c} \cdot F$$

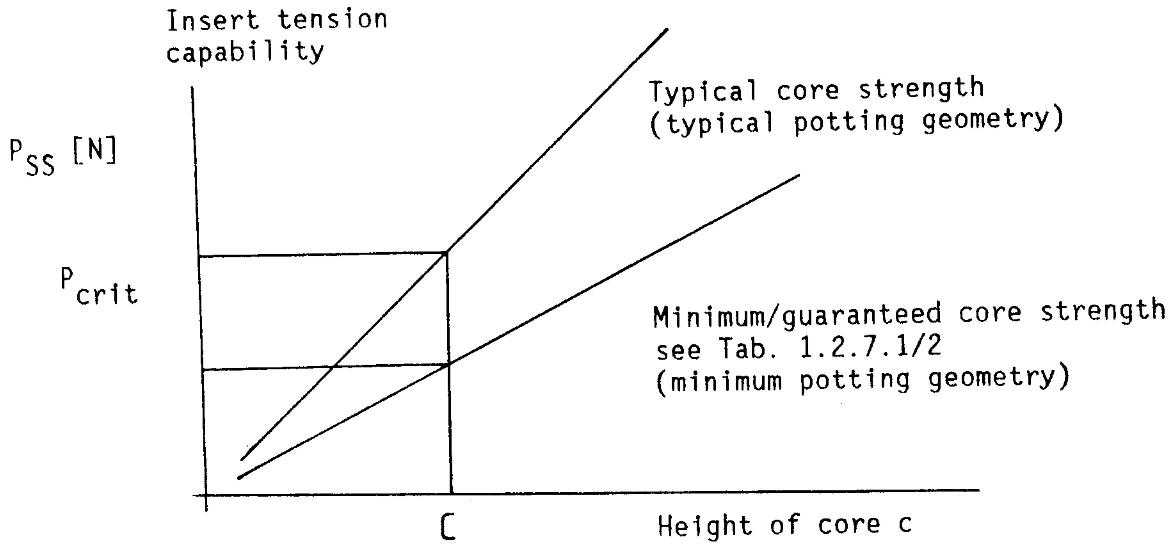
with $\tau_c = \tau_{c_{crit\ min}}$ and $F = P_{SS}$ the first term is known

$$\frac{\tau_{c_{crit_{min}}}}{P_{SS_{min}}} = \frac{C^* \cdot Kr_{max}}{2\ \pi\ b_p \cdot c}$$

And therefore the circular stress τ_c under a load P

$$\tau_c = F \cdot \frac{\tau_{crit_{min}}}{P_{SS_{min}}}$$

$\tau_{crit_{min}}$ values may be taken from Table 1.2.7, para. 2.1.1, and $P_{SS_{min}}$ may be read from the plots presented in section 2.1.2.2, see sketch below.



For a core 3/16 - 5052 - .0007 p with a height of 30 mm, a facing of 0.4 mm Al and an insert diameter of 14 mm one gets from capability plots, para. 2.1.2.2, and Tab. 1.2.7.1/2.

$$\tau_{c_{min}} = \frac{0.57}{1290} \cdot P = 4.4 \cdot 10^{-4} \left[\frac{1}{mm^2}\right] \cdot P$$

This core stress τ_c is considered the maximum (axially symmetrical) gross value occurring in the vicinity of the fully potted body in an infinite sandwich plate. Consequently it does not contain

- o shear stress variation versus height induced by partial potting
- o influences from the edges close to the insert
- o influences from other inserts adjacent to the considered insert
- o secondary loading e.g. in plane, etc.

The local peak stress due to fatigue is therefore - related to the gross stress τ_c - expressed by a magnification factor K_t so that local stress becomes

$$\tau_{c_{local}} = \tau_c \cdot K_t$$

with $$K_t = \varepsilon \cdot \prod_{j=1}^{s} K_{t_j}$$

s = number of effects applicable and to be superimposed therefore

Table 2.4.1 summarises different causes for locally increased stresses and the relevant paragraphs showing how to establish the value of K_t in accordance with section 2.1, ultimate strength.

Cyclic torsion or bending of inserts shall be exluced by means of appropriate grouping of inserts. If significant cyclic torsion and/or bending cannot be excluded, the verification should be based on detailed tests.

Effect	Stress Concentration Factor K_t	Reference
Partial potting	$K_{tpp} = (c/h_p)^n$	n = 0.8 for Al core
Influence of free border*)	$K_{tFB} = \frac{1}{\eta^2_{FB}}$	η_{FB} see Para 2.3
Inserts close to each other*)	$K_{tAJ} = \frac{1}{\eta^2_{AJ}}$	η_{AJ} see Para 2.2
Elevated temperature*)	$K_{TN} = \frac{1}{\eta_{TH}}$	η_{TH} see Para 2.1.7
Long-term influences*)	$K_{tLT} = \frac{1}{\eta_{LT}}$	η_{LT} see Para 2.1.7
Combin. of normal loads F and shear loads Q	$K_{tQ} = 1$	provided the load Q act in plane of facing, see para 2.1.6

*) These values are for preliminary design and need to be supported by test.

Table 2.4.1: Estimate of Stress Concentration Factors K_t Allowing to Determine the Local Stress

$$\tau_{local} = \tau \cdot \prod_{i=1}^{s} K_{t_i}$$

Relevant for Fatigue Assessment

In this case - assuming that insert load is related linearly to acclera-tion - each set i, i+1 of cyclic load with constant amplitude is repre-sented by

Mean load	$P_{mean_{i,\ i+1}}$
Load amplitude	$P_{A_{i,\ i+1}}$
Number of cycles	$N_{i,\ i+1} = \bar{N}_{i+1} - \bar{N}_i$

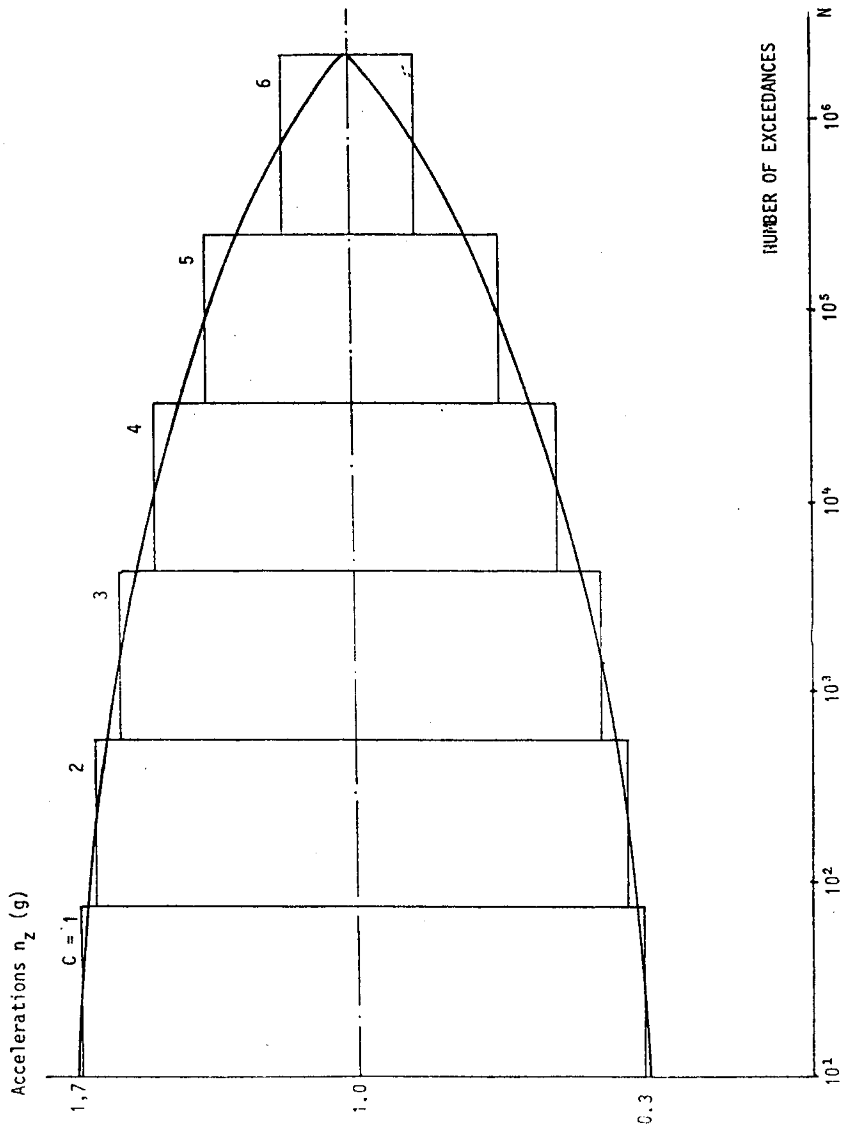


Fig. 2.4.1: Design Load Spectrum (Schematic)

2.4.2 Load/Stress Sequences

2.4.2.1 Constant Amplitude

The load or local stress sequence may be sinusoidal with an amplitude of local stress τ_a and a mean vaue of τ_{mean}

$$\tau = \tau_{mean} + \tau_{1a} \cdot \sin(\omega t)$$

The maximum core stress $\hat{\tau} = |\tau_{mean}| + \tau_a$ may be expressed under formulation of a mean stress ratio.

As the shear-loaded core webs under tension loads react in much the same way as under compressive load, the relevant R ratio becomes:

$$R = \frac{|\tau_{mean}| - \tau_A}{|\tau_{mean}| + \tau_A}$$

Sometimes it is preferable to use the maximum peak load $\hat{F}$ or $\hat{\tau}$, which is

$$\hat{F} = \frac{2 \cdot P_a}{1 - R}$$

$$\hat{\tau} = \frac{2 \cdot \tau_a}{1 - R}$$

2.4.2.2 Spectra Consisting of Several Sets of Constant Amplitudes

Different sets of load amplitude, R ratios and numbers of occurrences may be required by a design life spectrum. These spectra are also presented as a distribution: Fig. 2.4.1 shows, for example, the number of times a certain acceleration level is exceeded with constant mean acceleration, which may also be approximated by certain steps i.

$\bar{N}$ is the accumulated number of times a certain load level is exceeded.

As the amplitude $F_{A_{i,i+1}}$ is different for each step, the mean stress ratio R is different for each individual step, too.

If the total sequence of loading history is formed by different spectra with significantly different mean loads, special attention is necessary: sometimes these variations form the major part of the loading history with respect to fatigue damage (e.g. the ground/air/ground cycle). Such variations of mean loads are to be considered additional cycles.

2.4.3 Fatigue Damage

Damage with respect to fatigue is understood as an irreversible response of the insert system (especially the core) to cyclically repeated loading. After a certain accumulation of damage the item fails under the applied peak loading.

2.4.3.1 Life to Failure Under Constant Load Amplitude

The results of a cyclic loading test to failure are shown in the classical S/N plots which - in the case of insert application - can be approximated by

$$\tau_a = C \cdot N^{-\frac{1}{\kappa}} \qquad \text{for } \tau_{mean} + \tau_A < \tau_{c_{crit}}$$

The coefficient C depends on the mean stress τ_{mean}, which may be supposed to equal the alternating stress τ_A.

As the mean stress ratio R

$$R = \frac{|\tau_{mean}| - \tau_A}{|\tau_{mean}| + \tau_A}$$

is usually not constant, the following equation is more suitable for the analysis:

$$\tau_a = \left(\frac{2}{1-R}\right)^m \cdot C_A \cdot N^{-\frac{1}{\kappa}} \qquad \text{for} \quad \frac{\hat{\tau}}{K_t} < \tau_{c_{crit}}$$

Often, stresses are available for the maximum peak load $\hat{F}$ resulting in a maximum local peak stress $\hat{\tau}$. With

$$\hat{\tau} = \left(\frac{2}{1-R}\right) \cdot \tau_a$$

the above becomes

$$\hat{\tau} = \left(\frac{2}{1-R}\right)^{m+1} \cdot C_A \cdot N^{-\frac{1}{\kappa}}$$

together with

$$F = \frac{2\ \pi\ b_p\ c}{C^* \cdot K_{r_{max}}} \cdot \tau_c \qquad \text{See section 2.4.1.}$$

and

$$\hat{\tau}_c = \frac{\hat{\tau}}{K_t}$$

$$\hat{F} = \frac{2\ \pi\ b_p\ c}{C^* \cdot K_{r_{max}}\ K_t} \cdot \left(\frac{2}{1-R}\right)^{m+1} \cdot C_A \cdot N^{-\frac{1}{\kappa}}$$

or with

$$\tau_c = P_{SS}/\tau_{crit}$$

as shown in section 2.4.1.

$$\hat{F} = \left(\frac{P_{SS}}{\tau_{c_{crit_{min}}}}\right) \cdot \frac{1}{K_t} \cdot \left(\frac{2}{1-R}\right)^{m+1} \cdot C_A \cdot N^{-\frac{1}{\kappa}}$$

Coefficients for this equation for different honeycomb are given in Tab. 2.4.2. In accordance with static strength capabilities the "minimum values" are based upon minimum static core strength, minimum but proper potting size and lower boundary variation of the mathematical model.

The "typical values" are based upon average typical strength of core, typical potting geometry and typical values of the mathematical model.

For safe and reliable application where the failure of one single insert must be exluced it is advisable to use "minimum data" only.

The effect of variation of static strength of core τ_w is expected to influence the fatigue life behaviour of an actual batch of core material, too.

It was, however, found that this is true for low cycle fatigue areas only. For a life of 200,000 cycles the tolerable stress $\hat{\tau}$ was not influenced at all. For N = 1 the tolerable stress becomes α times $\hat{\tau}_{min(N=1)}$ if τ_w is actually $\tau_w \cdot \alpha$. Based upon those results achieved later, the linear reduction of the value C_A by the ratio $\tau_{w\ min}/\tau_{w\ actual}$ and $\tau_{w\ typ}/\tau_{w\ actual}$ in former issues was found rather crude and too conservative for $N < 200{,}000$. Therefore the values C_A and $1/\kappa$ were re-evaluated in accordance with the findings with Ref. [3] as presented in Tab. 4.2.2.

Type of Core	C_A	$\frac{1}{\kappa}$
3/16 - 5052 - .0007 p	1.1968	0.1129
3/16 - 5052 - .0010 p	(1.86)	(0.113)
3/16 - 5056 - .0007 p	1.4040	0.126
3/16 - 5056 - .0010 p	(2.19)	(0.126)
1/8 - 5052 - .0007 p	(1.86)	(0.113)
1/8 - 5052 - .0010 p	(2.83)	(0.113)
1/8 - 5052 - .0015 p	4.30	0.103
1/8 - 5056 - .0007 p	(2.19)	(0.126)
1/8 - 5056 - .0010 p	(3.32)	(0.126)

*) Values in brackets adapted from test results under reconsideration of core density.

$$\hat{F} = \frac{P_{SS}}{\tau_c} \cdot \left(\frac{h_p}{c}\right)^{0.8} \cdot \left(\frac{2}{1-R}\right)^{m+1} \cdot C_A \cdot N^{-\frac{1}{\kappa}}$$

$m+1$ = 0.3556

P_{SS} : static strength

τ_c : min. circular core shear strength

h_p : height of potting

c : height of core

Tab. 4.2.2: Values of the Coefficients to Determine the Peak Load $\frac{1}{\kappa}$ (based on minimum core properties and typical potting diameter ($h_{p\ typ}$); a scatter factor of 4 has to be used.)

For the convencience of the designer the fatigue life behaviour of inserts in the most frequently used core 3/16 - 5052 - $.0007_p$ has been provided as plots. The graphs are derived for core dimensions of 20 mm with an Al facing with 0.1 mm thickness. Corrective coefficients for other thickness of facings and height of core (CFF) are provided in tabular format as well as for the influence of partial potting (PPF).

- DIAGRAMS -

CYCLIC	3/16-5052-.0007 CORE	INSERT DIAMETER = 9 mm

Insert Height h_i = 9 mm   Facing Material Al 2024

CORRECTION FACTORS

FOR NON-STANDARD GEOMETRY

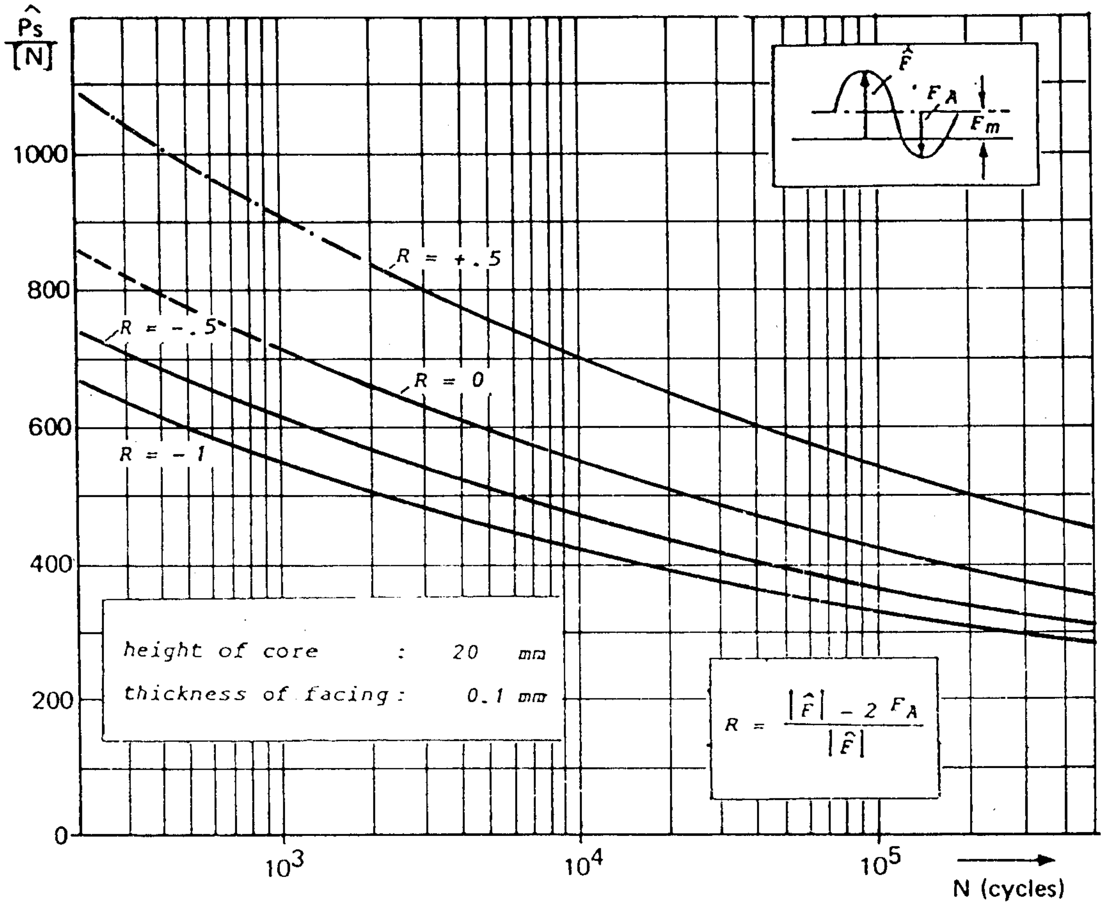
Multiply the given factors F_{cf} and F_{pp} with the load values given in graphic on the right.

HIGHT O.CORE mm	THICKN. FACING mm	C-F FACTOR F_{c-f}	PART.F. FACTOR F_{PP}	PROD.OF FACTORS $F_{c-f} * F_{PP}$
10	0.1	0.8980	0.6473	0.5812
20	0.1	1.0000	1.0000	1.0000
30	0.1	1.0692	1.1052	1.1817
40	0.1	1.1228	1.1506	1.2918
50	0.1	1.1670	1.1655	1.3601
10	0.2	1.0359	0.6473	0.6705
20	0.2	1.1153	1.0000	1.1153
30	0.2	1.1738	1.1052	1.2973
40	0.2	1.2206	1.1506	1.4044
50	0.2	1.2600	1.1655	1.4685
10	0.3	1.1994	0.6473	0.7763
20	0.3	1.2497	1.0000	1.2497
30	0.3	1.2944	1.1052	1.4306
40	0.3	1.3326	1.1506	1.5333
50	0.3	1.3660	1.1655	1.5921
10	0.4	1.3870	0.6473	0.8977
20	0.4	1.4020	1.0000	1.4020
30	0.4	1.4302	1.1052	1.5807
40	0.4	1.4581	1.1506	1.6777
50	0.4	1.4842	1.1655	1.7299
10	0.5	1.5986	0.6473	1.0347
20	0.5	1.5715	1.0000	1.5715
30	0.5	1.5804	1.1052	1.7467
40	0.5	1.5964	1.1506	1.8368
50	0.5	1.6141	1.1655	1.8813
10	0.6	1.8357	0.6473	1.1881
20	0.6	1.7584	1.0000	1.7584
30	0.6	1.7448	1.1052	1.9285
40	0.6	1.7472	1.1506	2.0103
50	0.6	1.7553	1.1655	2.0458
10	0.7	2.1007	0.6473	1.3597
20	0.7	1.9635	1.0000	1.9635
30	0.7	1.9238	1.1052	2.1262
40	0.7	1.9104	1.1506	2.1981
50	0.7	1.9077	1.1655	2.2234
10	0.8	2.3972	0.6473	1.5516
20	0.8	2.1882	1.0000	2.1882
30	0.8	2.1180	1.1052	2.3408
40	0.8	2.0866	1.1506	2.4008
50	0.8	2.0715	1.1655	2.4144

CYCLIC	3/16-5052-.0007 CORE	INSERT DIAMETER = 9 mm

Insert Height h_I = 9 mm Facing Material Al 2024

Parameter : R



For Standard Geometry (f = .1 mm; c = 20 mm) as above :

$$\boxed{\hat{P}_S = 1208.2 * \left(\frac{2}{1-R}\right)^{0.3556} * N^{-.1129}}$$ $\hat{P}_S < P_{SS}$

For other geometry :

$$\boxed{\hat{P} = \hat{P}_S * F_{C-F} * F_{PP}}$$ (see table left)

CYCLIC	3/16-5052-.0007 CORE	INSERT DIAMETER = 11 mm

Insert Height h_i = 9 mm Facing Material Al 2024

CORRECTION FACTORS

FOR NON-STANDARD GEOMETRY

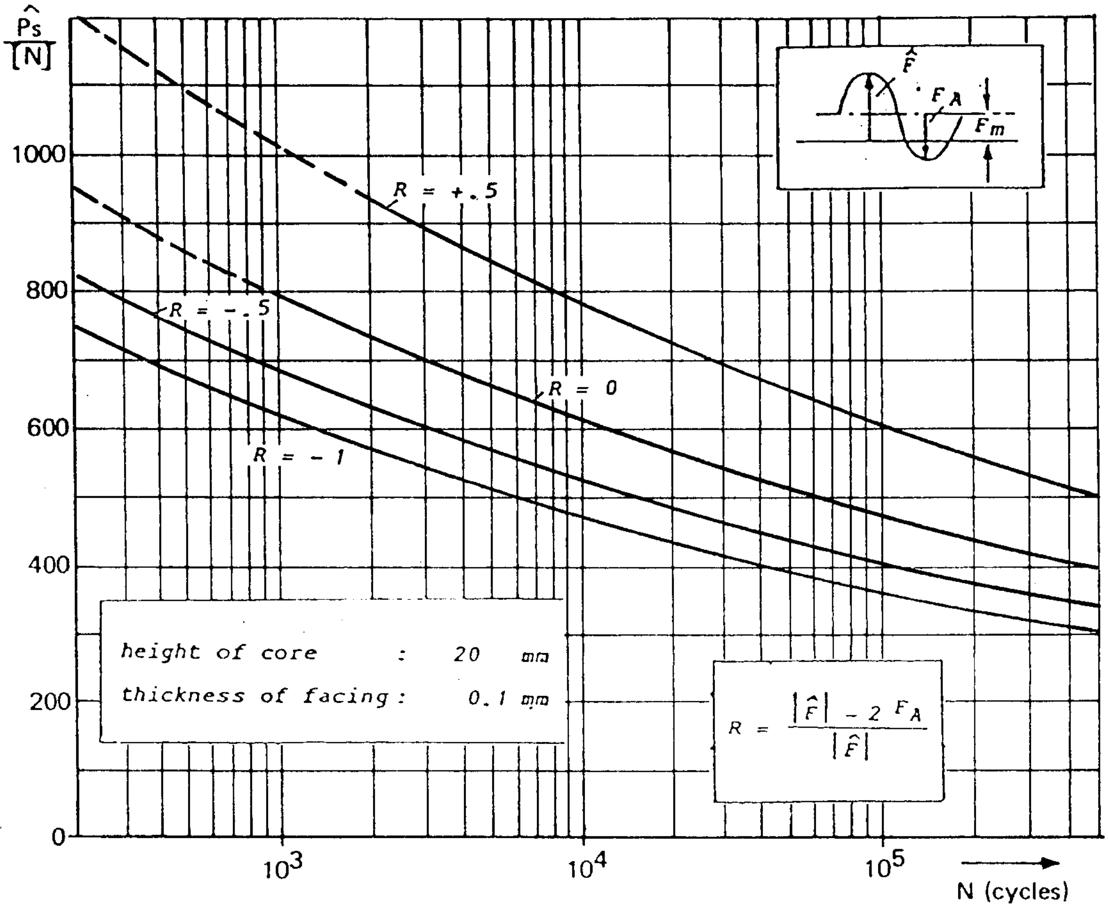
Multiply the given factors F_{cf} and F_{pp} with the load values given in graphic on the right.

HIGHT O.CORE mm	THICKN. FACING mm	C-F FACTOR F_{cf}	PART.P. FACTOR F_{pp}	PROD.OF FACTORS $F_{cf} * F_{pp}$
10	0.1	0.8961	0.6473	0.5800
20	0.1	1.0000	1.0000	1.0000
30	0.1	1.0703	1.1052	1.1829
40	0.1	1.1247	1.1506	1.2940
50	0.1	1.1695	1.1655	1.3631
10	0.2	1.0227	0.6473	0.6620
20	0.2	1.1059	1.0000	1.1059
30	0.2	1.1664	1.1052	1.2892
40	0.2	1.2146	1.1506	1.3975
50	0.2	1.2550	1.1655	1.4627
10	0.3	1.1718	0.6473	0.7584
20	0.3	1.2286	1.0000	1.2286
30	0.3	1.2766	1.1052	1.4110
40	0.3	1.3170	1.1506	1.5154
50	0.3	1.3520	1.1655	1.5757
10	0.4	1.3418	0.6473	0.8685
20	0.4	1.3669	1.0000	1.3669
30	0.4	1.4001	1.1052	1.5474
40	0.4	1.4313	1.1506	1.6468
50	0.4	1.4596	1.1655	1.7012
10	0.5	1.5325	0.6473	0.9919
20	0.5	1.5203	1.0000	1.5203
30	0.5	1.5362	1.1052	1.6979
40	0.5	1.5567	1.1506	1.7911
50	0.5	1.5775	1.1655	1.8386
10	0.6	1.7446	0.6473	1.1292
20	0.6	1.6885	1.0000	1.6885
30	0.6	1.6846	1.1052	1.8619
40	0.6	1.6929	1.1506	1.9479
50	0.6	1.7053	1.1655	1.9875
10	0.7	1.9798	0.6473	1.2815
20	0.7	1.8721	1.0000	1.8721
30	0.7	1.8454	1.1052	2.0396
40	0.7	1.8399	1.1506	2.1170
50	0.7	1.8427	1.1655	2.1477
10	0.8	2.2405	0.6473	1.4502
20	0.8	2.0719	1.0000	2.0719
30	0.8	2.0190	1.1052	2.2314
40	0.8	1.9979	1.1506	2.2987
50	0.8	1.9899	1.1655	2.3193

CYCLIC	3/16-5052-.0007 CORE	INSERT DIAMETER = 11 mm

Insert Height h_I = 9 mm   Facing Material Al 2024

Parameter : R



For Standard Geometry (f = .1 mm; c = 20 mm) as above:

$$\hat{P}_S = 1344.6 \cdot \left(\frac{2}{1-R}\right)^{0.3556} * N^{-.1129} \qquad \hat{P}_s < P_{ss}$$

For other geometry:

$$\hat{P} = \hat{P}_S * F_{C-F} * F_{PP} \qquad \text{(see table left)}$$

CYCLIC	3/16-5052-.0007 CORE	INSERT DIAMETER = 14 mm

Insert Height h_i = 9 mm Facing Material Al 2024

CORRECTION FACTORS

FOR NON-STANDARD GEOMETRY

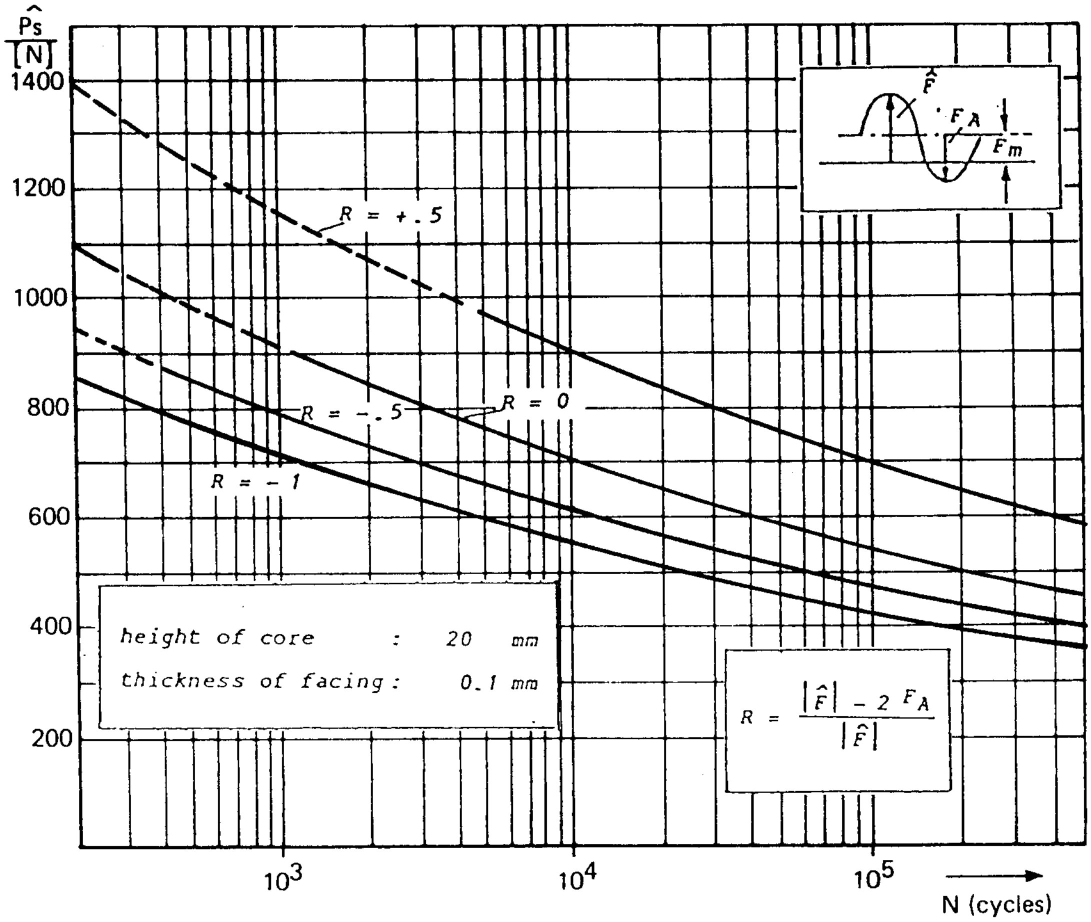
Multiply the given factors F_{cf} and F_{pp} with the load values given in graphic on the right.

HIGHT C.CORE mm	THICKN. FACING mm	C-F FACTOR F_{c-f}	PART.P. FACTOR F_{PP}	PROD.OF FACTORS $F_{c-f} * F_{PP}$
10	0.1	0.8938	0.6473	0.5785
20	0.1	1.0000	1.0000	1.0000
30	0.1	1.0716	1.1052	1.1844
40	0.1	1.1270	1.1506	1.2967
50	0.1	1.1726	1.1655	1.3667
10	0.2	1.0072	0.6473	0.6519
20	0.2	1.0949	1.0000	1.0949
30	0.2	1.1577	1.1052	1.2796
40	0.2	1.2075	1.1506	1.3893
50	0.2	1.2491	1.1655	1.4558
10	0.3	1.1393	0.6473	0.7374
20	0.3	1.2038	1.0000	1.2038
30	0.3	1.2557	1.1052	1.3878
40	0.3	1.2986	1.1506	1.4942
50	0.3	1.3354	1.1655	1.5565
10	0.4	1.2891	0.6473	0.8344
20	0.4	1.3258	1.0000	1.3258
30	0.4	1.3648	1.1052	1.5084
40	0.4	1.3996	1.1506	1.6104
50	0.4	1.4307	1.1655	1.6675
10	0.5	1.4559	0.6473	0.9424
20	0.5	1.4604	1.0000	1.4604
30	0.5	1.4844	1.1052	1.6407
40	0.5	1.5101	1.1506	1.7375
50	0.5	1.5346	1.1655	1.7886
10	0.6	1.6400	0.6473	1.0615
20	0.6	1.6073	1.0000	1.6073
30	0.6	1.6144	1.1052	1.7843
40	0.6	1.6295	1.1506	1.8749
50	0.6	1.6468	1.1655	1.9193
10	0.7	1.8423	0.6473	1.1924
20	0.7	1.7666	1.0000	1.7666
30	0.7	1.7544	1.1052	1.9391
40	0.7	1.7579	1.1506	2.0226
50	0.7	1.7670	1.1655	2.0594
10	0.8	2.0641	0.6473	1.3360
20	0.8	1.9388	1.0000	1.9388
30	0.8	1.9048	1.1052	2.1053
40	0.8	1.8952	1.1506	2.1806
50	0.8	1.8952	1.1655	2.2088

CYCLIC	3/16-5052-.0007 CORE	Insert Diameter = 14 mm

Insert Height h_I = 9 mm   Facing Material Al 2024

Parameter : R



For Standard Geometry (f = .1 mm; c = 20 mm) as above :

$$\hat{P}_S = 1548.8 \left(\frac{2}{1-R}\right)^{0.3556} N^{-.1129} \qquad \hat{P}_S < P_{SS}$$

For other geometry :

$$\hat{P} = \hat{P}_S \, F_{C-F} \, F_{PP}$$ *(see table left)*

CYCLIC	3/16-5052-.0007 CORE	INSERT DIAMETER =17,5mm

Insert Height h_I = 9 mm Facing Material Al 2024

CORRECTION FACTORS

FOR NON-STANDARD GEOMETRY

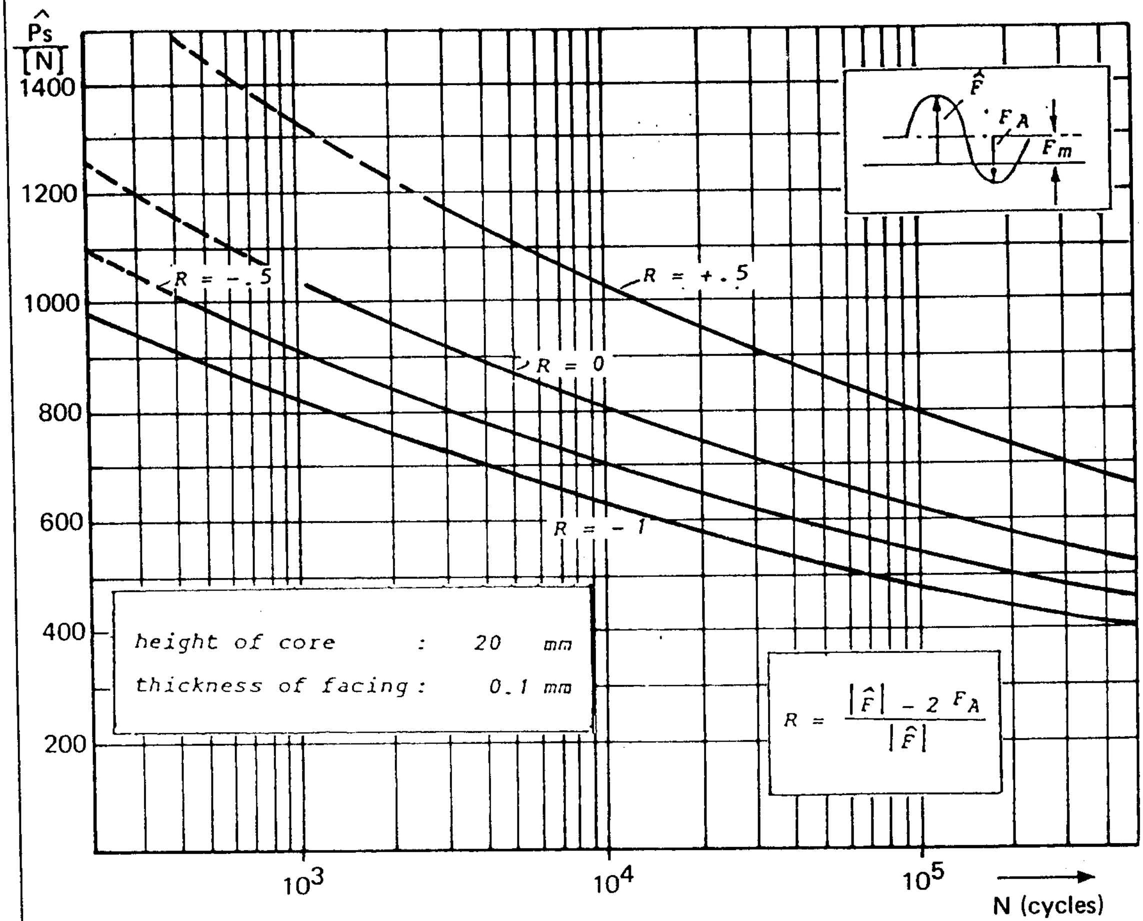
Multiply the given factors F_{cf} and F_{pp} with the load values given in graphic on the right.

HIGHT O.CORE mm	THICKN. FACING mm	C-F FACTOR F_{c-f}	PART.P. FACTOR F_{PP}	PROD.OF FACTORS $F_{c-f} * F_{PP}$
10	0.1	0.8918	0.6473	0.5772
20	0.1	1.0000	1.0000	1.0000
30	0.1	1.0729	1.1052	1.1858
40	0.1	1.1291	1.1506	1.2991
50	0.1	1.1754	1.1655	1.3700
10	0.2	0.9933	0.6473	0.6430
20	0.2	1.0850	1.0000	1.0850
30	0.2	1.1499	1.1052	1.2710
40	0.2	1.2011	1.1506	1.3820
50	0.2	1.2438	1.1655	1.4496
10	0.3	1.1107	0.6473	0.7189
20	0.3	1.1817	1.0000	1.1817
30	0.3	1.2371	1.1052	1.3673
40	0.3	1.2823	1.1506	1.4754
50	0.3	1.3207	1.1655	1.5393
10	0.4	1.2428	0.6473	0.8044
20	0.4	1.2896	1.0000	1.2896
30	0.4	1.3335	1.1052	1.4738
40	0.4	1.3716	1.1506	1.5782
50	0.4	1.4051	1.1655	1.6377
10	0.5	1.3891	0.6473	0.8991
20	0.5	1.4079	1.0000	1.4079
30	0.5	1.4389	1.1052	1.5903
40	0.5	1.4689	1.1506	1.6901
50	0.5	1.4967	1.1655	1.7444
10	0.6	1.5495	0.6473	1.0029
20	0.6	1.5364	1.0000	1.5364
30	0.6	1.5528	1.1052	1.7162
40	0.6	1.5738	1.1506	1.8108
50	0.6	1.5952	1.1655	1.8593
10	0.7	1.7243	0.6473	1.1161
20	0.7	1.6751	1.0000	1.6751
30	0.7	1.6751	1.1052	1.8513
40	0.7	1.6861	1.1506	1.9400
50	0.7	1.7005	1.1655	1.9820
10	0.8	1.9144	0.6473	1.2391
20	0.8	1.8241	1.0000	1.8241
30	0.8	1.8057	1.1052	1.9958
40	0.8	1.8057	1.1506	2.0776
50	0.8	1.8124	1.1655	2.1123

CYCLIC	3/16-5052-.0007 CORE	INSERT DIAMETER = 17.5 mm

Insert Height h_I = 9 mm   Facing Material Al 2024

Parameter : R



For Standard Geometry (f = .1 mm; c = 20 mm) as above:

$$\hat{P}_S = 1784.9 * \left(\frac{2}{1-R}\right)^{0.3556} * N^{-.1129}$$

$\hat{P} < P_{ss}$

For other geometry :

$$\hat{P} = \hat{P}_S * F_{C-F} * F_{PP}$$

(see table left)

CYCLIC	3/16-5052-.0007 CORE	INSERT DIAMETER = 22 mm

Insert Height h_I = 9 mm Facing Material Al 2024

CORRECTION FACTORS

FOR NON-STANDARD GEOMETRY

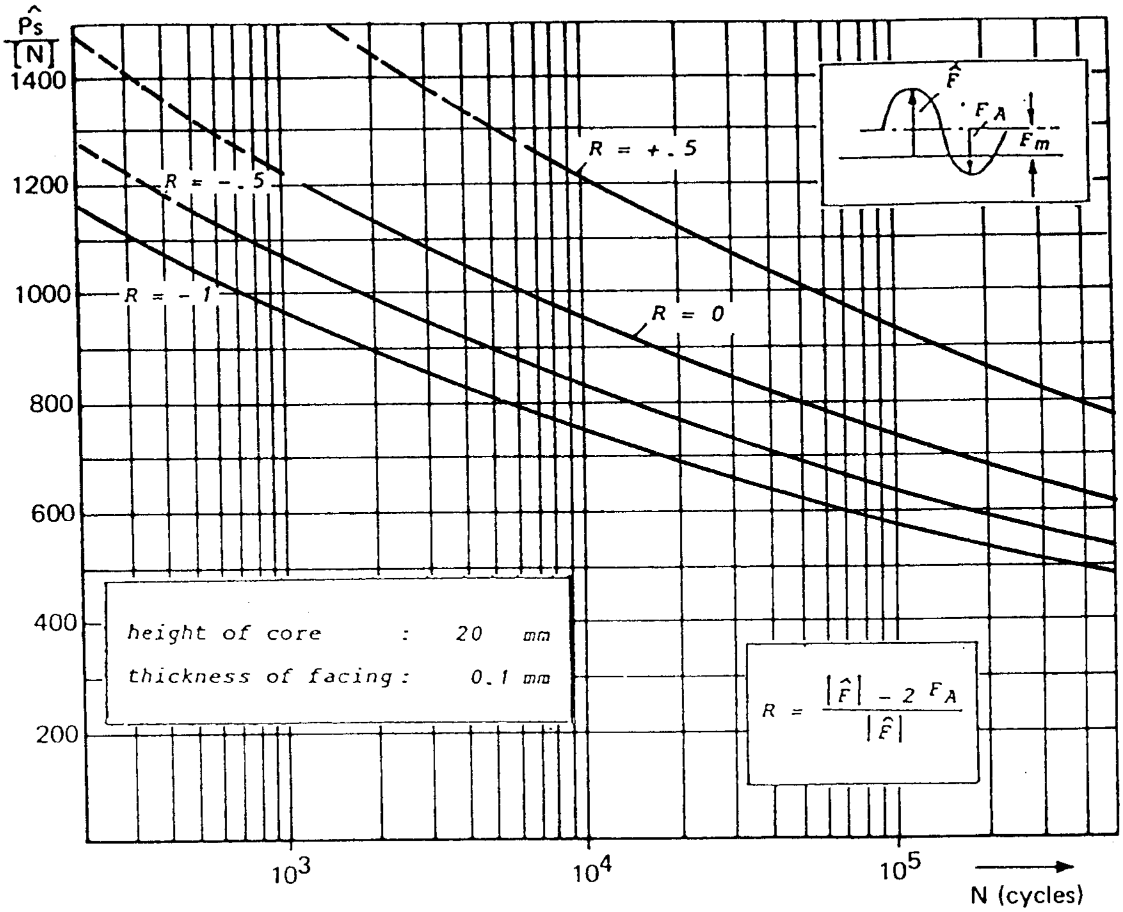
Multiply the given factors F_{cf} and F_{pp} with the load values given in graphic on the right.

HIGHT O.CORE mm	THICKN. FACING mm	C-F FACTOR F_{c-f}	PART.F. FACTOR F_{pp}	PROD.OF FACTORS $F_{c-f} * F_{pp}$
10	0.1	0.8897	0.6473	0.5759
20	0.1	1.0000	1.0000	1.0000
30	0.1	1.0741	1.1052	1.1871
40	0.1	1.1312	1.1506	1.3016
50	0.1	1.1783	1.1655	1.3733
10	0.2	0.9800	0.6473	0.6343
20	0.2	1.0754	1.0000	1.0754
30	0.2	1.1423	1.1052	1.2626
40	0.2	1.1949	1.1506	1.3748
50	0.2	1.2385	1.1655	1.4435
10	0.3	1.0832	0.6473	0.7011
20	0.3	1.1605	1.0000	1.1605
30	0.3	1.2191	1.1052	1.3474
40	0.3	1.2664	1.1506	1.4571
50	0.3	1.3064	1.1655	1.5226
10	0.4	1.1986	0.6473	0.7758
20	0.4	1.2548	1.0000	1.2548
30	0.4	1.3035	1.1052	1.4406
40	0.4	1.3447	1.1506	1.5472
50	0.4	1.3804	1.1655	1.6088
10	0.5	1.3256	0.6473	0.8580
20	0.5	1.3577	1.0000	1.3577
30	0.5	1.3952	1.1052	1.5420
40	0.5	1.4295	1.1506	1.6447
50	0.5	1.4603	1.1655	1.7020
10	0.6	1.4640	0.6473	0.9476
20	0.6	1.4690	1.0000	1.4690
30	0.6	1.4940	1.1052	1.6512
40	0.6	1.5205	1.1506	1.7495
50	0.6	1.5459	1.1655	1.8018
10	0.7	1.6138	0.6473	1.0446
20	0.7	1.5885	1.0000	1.5885
30	0.7	1.5996	1.1052	1.7680
40	0.7	1.6176	1.1506	1.8612
50	0.7	1.6370	1.1655	1.9080
10	0.8	1.7755	0.6473	1.1492
20	0.8	1.7161	1.0000	1.7161
30	0.8	1.7120	1.1052	1.8922
40	0.8	1.7207	1.1506	1.9798
50	0.8	1.7336	1.1655	2.0205

CYCLIC	3/16-5052-.0007 CORE	INSERT DIAMETER = 22 mm

Insert Height h_I = 9 mm   Facing Material Al 2024

Parameter : R



For Standard Geometry (f = .1 mm; c = 20 mm) as above:

$$\hat{P}_S = 2092.0 * \left(\frac{2}{1-R}\right)^{0.3556} * N^{-.1129} \qquad \hat{P}_S < P_{SS}$$

For other geometry:

$$\hat{P} = \hat{P}_S * F_{C-F} * F_{PP}$$ (see table left)

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2.4.3.2 Damage Accumulation

According to Palmgreen/Miner a linear accumulation of damage may be used to assess the fatigue behaviour of inserts under cyclic loads.

Under constant-amplitude load an accumulated sum of damage

$$D_i = \Sigma \frac{n_i}{N_i} \leq k$$

n_i = number of cycles applied

N_i = number of cycles applicable up to failure under load amplitude.

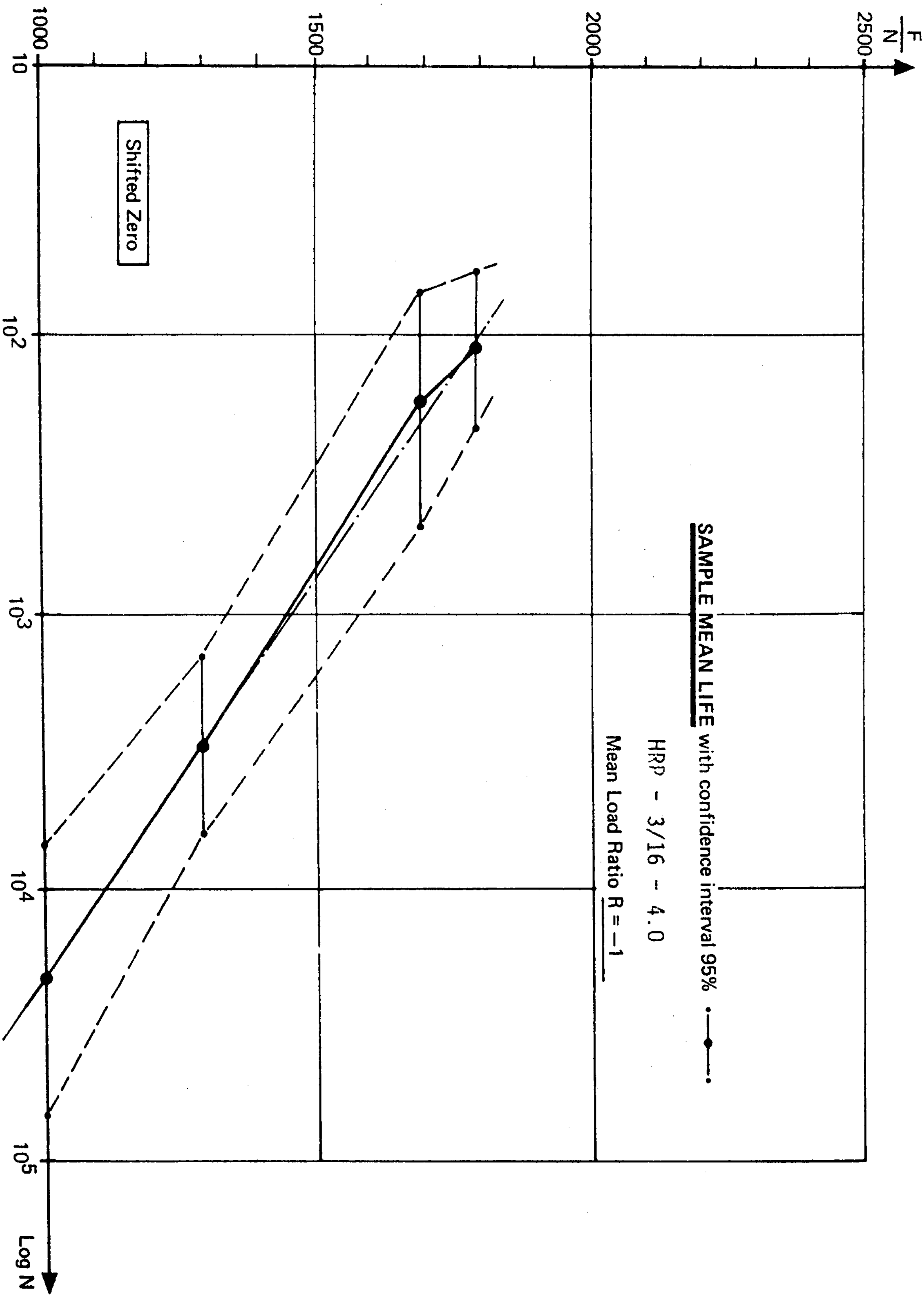
is acceptable if the degree of confidence in the fatigue data and the probability of having no failure are in agreement with the requirement. A value of k equal to 0.25 is commonly used for initial assessments.

2.4.4 Fatigue Behaviour of Inserts in Non-Metallic Core

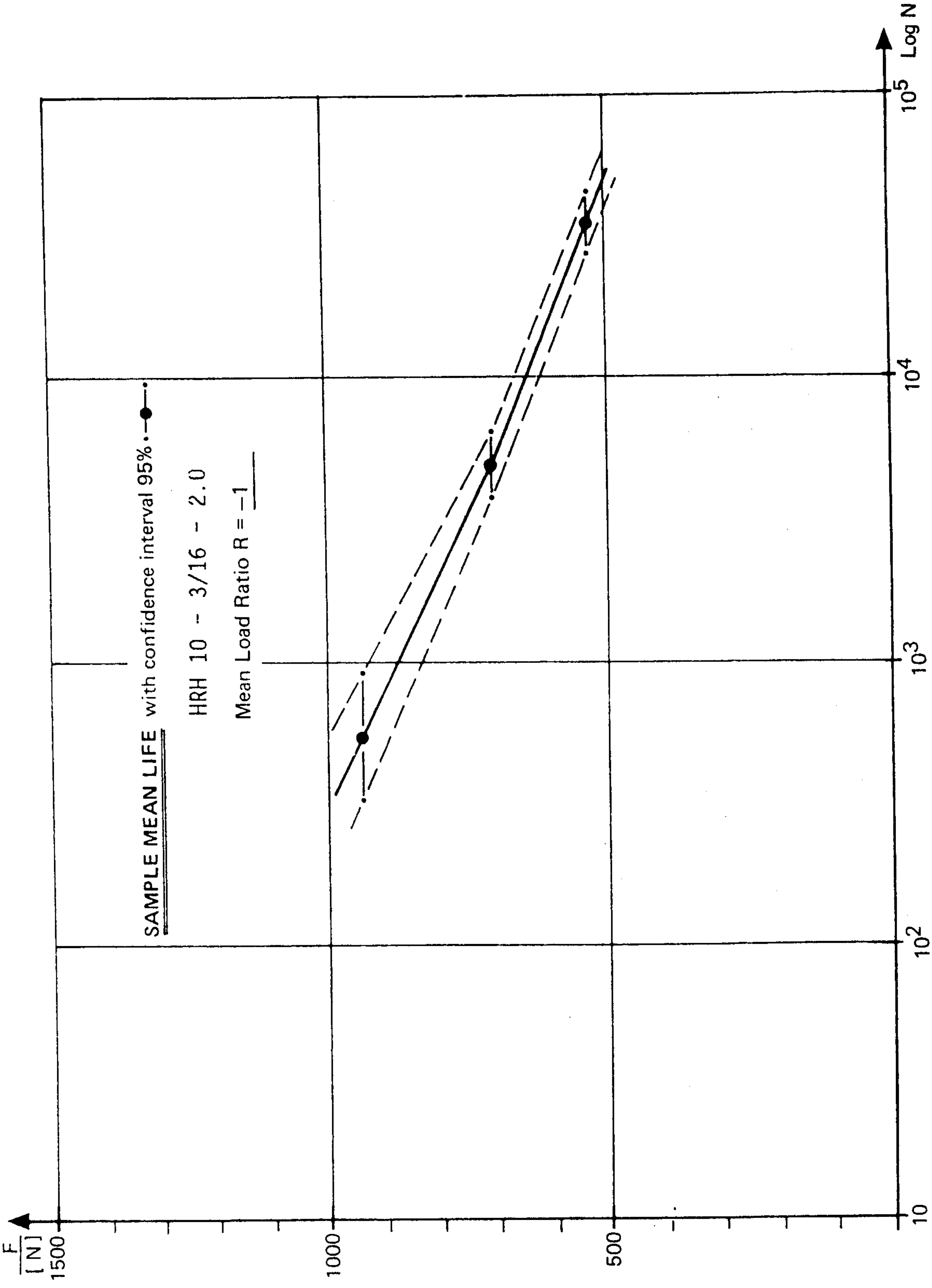
Fatigue data of inserts in sandwich panel utilizing non-metallic core (NOMEX, GFRP) are not available to such an extent that a model can be generated covering all insert and panel configurations.

However, two S-N curves are presented for the worst R ratio (R = -1). They should allow for a first estimate of the fatigue life in an early design phase, subject of supporting tests.

A general remark needs to be made with respect to the sensitivity of NOMEX/GFRP core with respect to severe partial potting ($h_c >> h_p$).



Fatigue Life : GFRP Core



Fatigue Life : NOMEX Core

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3.0 INSERT SYSTEM MANUFACTURING

It is assumed that the sandwich is manufactured in accordance with the related standards (e.g. MIL HDBK 23). Special aspects of the influence of core strength on insert capabilities are to be covered in accordance with sections 1.2.2.2.3 and 4.1.1.

With respect to the implementation of an insert element into a sandwich panel, there are two activities:

a) bore hole drilling (see section 3.1)
b) potting of inserts (see section 3.2).

3.1 Drilling of Bore Holes

This procedure is applicable for the drilling of bore holes into honeycomb sandwich panels necessary for the arrangement of potted inserts.

It allows the preparation of defined bore holes without damaging the surrounding core.

3.1.1 Applicable Documents

This procedure is derived from ERNO experience (ERN 3442/17-15, Manufacture Procedure Potting Process).

3.1.2 Processing

The drilling of bore holes for inserts can be realized by two different steps:

1. Drilling of face sheet and cutting of honeycomb core
2. Drilling of face sheet and honeycomb core

In detail, the procedures are as follows:

3.1.2.1 Drilling of Face Sheet and Cutting of Honeycomb Core

a) Drilling of Face Sheet Bore Holes

The location of the insert shall be fixed by a centre bore of 6 or 8 mm diameter.

A special drill which only cuts the outer diameter of the bore separates a face sheet disk, No. 2 of Fig. 3.2.

The face sheet disk will be pulled off the core with a pair of tweezers. When a coordinate drilling machine is available, the special drill can be applied without setting a centre bore.

The bore hole in the face sheet shall be within a tolerance of 0 to +0.03 mm of the nominal diameter of the insert.

b) Cutting of Honeycomb Core

A punching tube moves downwards perpendicular to the sandwich plate up to a depth required to the insert height, section 1.2.3.2.3, thus cutting a cylindrical part of the core. Simultaneously a drill acting inside the tube removes the cut cylindrical core, the tube acting as a drill-jig bush. By this technique, the requirements of section 3.1.3.3 can be reliably maintained.

Fig. 3.1 shows the arrangement and function of the combined tool in principle and Fig. 3.2 shows a picture of the individual tools involved in making bore holes.

The single tools are:

1. Drill to set a centre bore into the face sheet
2. Special drill for cutting the face sheet bore hole
3. Punching tube for non-rotating cutting of core
4. Combination of punching tube with the inner core milling tool
5. Inner milling tool separately

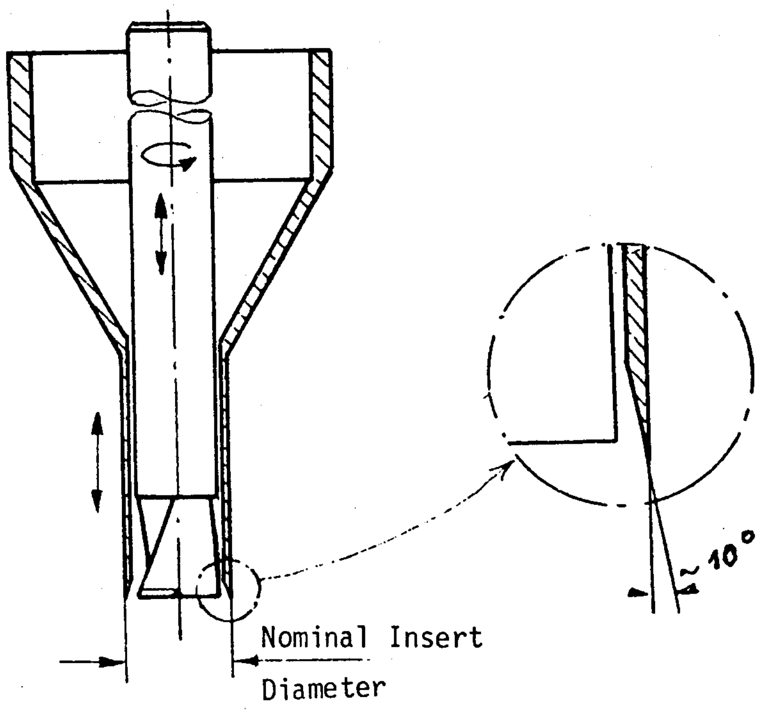

Fig. 3.1: Combined Punch and Drill Tool

The depth of the bore hole shall exceed the insert height by 3 to 4 mm.

After adequate machining, bent or dislocated core cells shall not exist or, if identified, shall be removed or shall be straightened so that the insert potting mass can flow undisturbed into all open honeycomb cells.

The use of lubrication or cooling liquid is not admissible.

The set of tools is as follows:

1. Drill to set a centre bore into the face sheet
2. Special drill for cutting the face sheet bore hole
3. Punching tube for non-rotating cutting of core
4. Combination of punching tube with the inner core milling tool
5. Inner milling tool separately

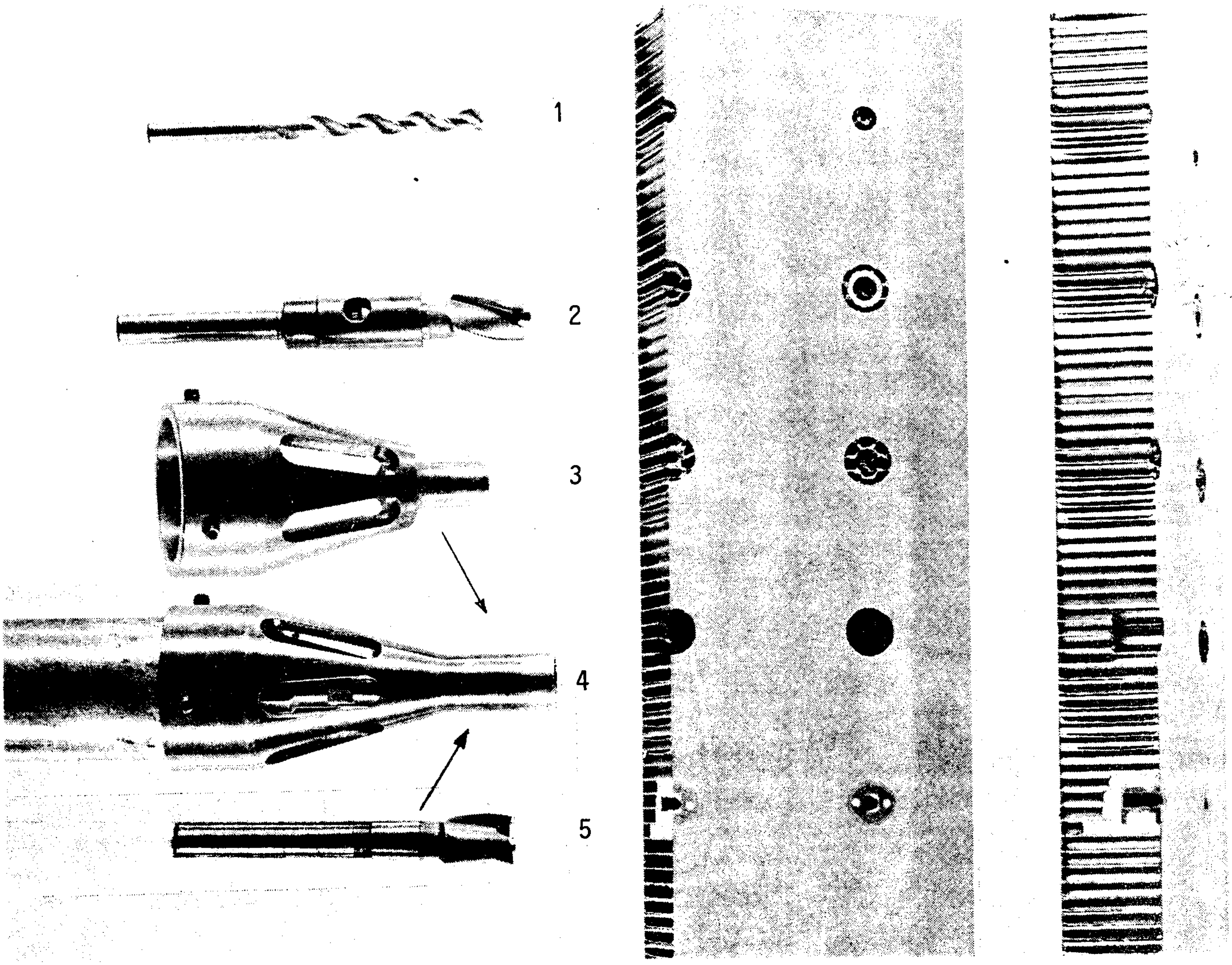

Fig. 3.2: Survey of Tools and Tool-Related Processing Steps

3.1.2.2 Drilling of Face Sheet and Honeycomb Core

A drill (diameter: d_i - 2 mm) moves downwards perpendicular to the sandwich plate up to the depth required to the insert height, section 1.2.3.2.3. Subsequently the bore hole is extended on the nominal insert diameter within a tolerance of 0 to 0.03 mm by using a reamer.

The use of lubrication or cooling liquid is not admissible.

After adequate machining, bent or dislocated core cells shall not exist or, if identified, shall be removed or be straightened so that the insert potting mass can flow undisturbed into all open honeycomb cells.

3.1.2.3 Process Control

The process of bore hole preparation is to be controlled in accordance with the quality assurance provision of section 5.2.

3.1.2.4 Disturbances of the Bore Drilling Process

Drilling is easy in the case of perforated aluminum cores. Unperforated core with small foil thickness and the tight type of NOMEX and GFRP core, however, create special conditions owing to the possibly low gas pressure within the closed cells, caused by the sandwich bonding process.

This may cause difficulties as a result of:

- o deformation of face sheet on the backside in the range of the bore diameter;
- o core failure due to instability of cell walls.

Although it is difficult to avoid such distortions (e.g. by venting with the aid of a needle) it is useful to know that they are likely to occur.

3.2 Insert Potting

3.2.1 Field of Application

This manufacturing procedure is applicable for the potting of inserts into sandwich structures where inserts for space vehicles are to be installed.

3.2.2 Applicable Documents

The documents listed below form part of this manufacturing procedure to the extent mentioned. Unless otherwise specified, the respective latest German issue of these documents applies.

3.2.2.1 Specifications, Procedures, Standards

ENN 366[1])	-	Inserts for sandwich structures, closed, self-locking with floating and removable nut, screw securing
ENN 386[1])	-	Inserts for sandwich structures closed, self-locking
ENN 398[1])	-	Inserts for sandwich constructions, closed, with screw locking helical coil insert
ENN 34602[1])	-	Bonding tabs
LN 9368[2])	-	Designation of the surface treatment
DIN 50014[2])	-	Standard climate conditions
RL 0008021	-	Instructions for the issuance of failure messages and failure elimination

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[1]) from MBB/ERNO

[2]) from Beuth-Verlag, Germany

3.2.2.2 Other Documents

- Product Data SLE 3010 7-29-70

- Processing Instructions for "Lekutherm" X227 + T3 of Bayer company

- UVV 11.2 (VBG 87) - Application of toxic, volatile, non-flammable solvents for cleaning purposes

- VBG 81 - Application of adhesive with easily volatile, flammable solvents.

3.2.3 Technical Requirements

3.2.3.1 General Requirements

3.2.3.1.1 Environmental Conditions

The environmental conditions for the mixing, potting, and curing of the inserts have to meet the standard climatic conditions 23/50 to DIN 50014. For manufacture, normal laboratory conditions are applicable.

3.2.3.1.2 Protection of the Cover Sheets

The cover sheets of the sandwich structure are to be receive a protective layer (foil, sticky-back paper). The protective layer shall be easily removable and shall not leave behind any residues that are difficult to eradicate.

3.2.3.1.3 Pre-Treatment of the Inserts

Before potting, the inserts are to be degreased in a perchlorethylene steam bath. (Identification No. 0001.-LN 9368).

The time between degreasing and potting must not exceed 8 hours.

Alternatively, an acetone bath may be used, but this requires frequent changing of the contaminated liquid.

After the degreasing process, the inserts must be handled with clean lint-free gloves or with the aid of tongs.

3.2.3.2 Workpiece and Manufacturing Means

3.2.3.2.1 Workpiece

Sandwich structure plate according to the workshop drawing.

3.2.3.2.2 Inserts

Inserts according to ENN 366
Inserts according to ENN 379
Inserts according to ENN 386
Inserts according to ENN 398
Inserts according to other standards
Inserts according to workshop drawing.

3.2.3.2.3 Potting Resin

For potting of inserts, resin systems listed in sections 3.2.3.2.3.1 and 3.2.3.2.3.2 are suitable. It is characteristic of both systems that the high content of glass bubbles gives rise to a light viscous paste, which can only be processed with the aid of a compressed air cartridge (semco-cartridge). The specific gravity of the resin mixture is 0.6 to 0.7 kg/dm^n.

3.2.3.2.3.1 Shur-Lok Resin System SLE 3010

This is especially suitable for inserts. The resin and hardener components which are separately contained in the cartridge cases are mixed according to the attached preparation instructions and can then be processed in the original cartridge (refer to product data SLE 3010 7-29-70).

Processing time:	20 min. at RT
Cure cycle time:	24 hrs. at RT
Storage time:	max. 12 months at RT.

The optimum characteristics are reached after 7 days at R.T.

This resin does not fulfil the outgassing requirements of 1 % TWL and 0.1 % VCM.

3.2.3.2.3.2 Insert Potting Foam Lekutherm X227 + T3 (Bayer Company)

The mixing ratio is:

- o Lekutherm X227 resin: 100 parts by weight
- o T3 hardener: 30 parts by weight

After mixing, add

- o Microballoons B23-500: 40 parts by weight (3M Comp.)

Through mixing results in a soft paste, which does not flow in small quantities (1 to 2 cm^3 will adhere to the mixing spatula). Deviation from the suitable viscosity must be corrected by addition of microballoons or pure resin mixture.

The insert potting foam prepared in this way is then to be placed in a Semco cartridge without cavities. The orifice nozzle should have of a diameter of approximately 2 mm (see handling procedure KL43022).

Processing time:	70 min. at RT	
Cure cycle time:	24 hrs at RT	(for final machining, section 3.2.3.3.5)
	48 hrs at RT	(in case of repair, section 3.2.3.7)
Storage time:	12 months at RT at maximum	

Adjustment of air pressure 2.5 to 3.5 bar.

3.2.3.3 Manufacturing Sequence

3.2.3.3.1 Drilling of the Bore Holes

Bore hole drilling is described in section 3.1 of the relevant process specification.

3.2.3.3.2 Insertion of the Inserts

3.2.3.3.2.1 Sandwich with Perforated Core

The protective layer of the cover sheets in the vicinity of the holes is to be removed to the extent required by the bonding tabs according to ENN 34602.

The inserts are to be provided with bonding tabs in accordance with ENN 34602 such that the injection holes are congruent. Subsequently the inserts are to be inserted into the respective bore holes in such way that they are kept at the same with respect to the cover sheet by the bonding tabs.

If the distance between the inserted insert and the cover sheet at the bottom of the hole is less than 3 mm, the bottom of the insert is to be provided with the appropriate amount of insert potting compound prior to insertion so that the loose cover sheet is supported when the insert is in position.

If 2 or more inserts are located in the same position, particular care must be taken to ensure that the opposite inserts do not lift during potting.

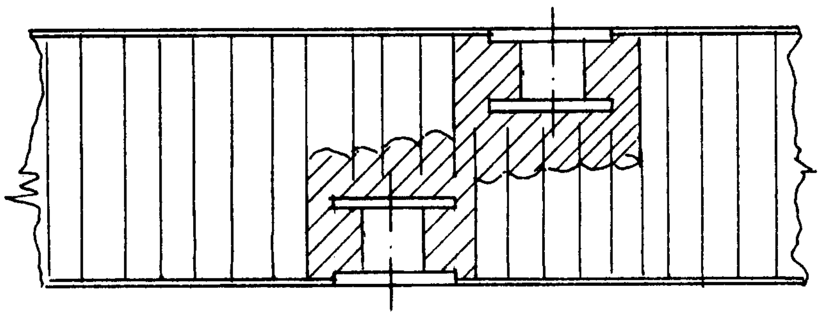


Figure 3.3: Inserts with Connected Potting Mass

3.2.3.3.2.2 Sandwich with Non-Perforated Core

For non-perforated core an additional action is required to allow air enclosed in the sandwich bore hole to be displaced by the resin. Otherwise cells underneath the insert will not be properly filled.

For this purpose, a venting tube has to be inserted into one of the insert bore holes until it touches the opposite face sheet (see Figure 3.4). The venting tube shall have the following range of sizes:

Inner diameter: > 0.3 mm
Outer diameter: ~ 1.5 mm

The ends shall be cut diagonally at an angle of approximately 45°. The tube must be of space-approved material if it is to remain in the potting. Otherwise it must be removed before curing.

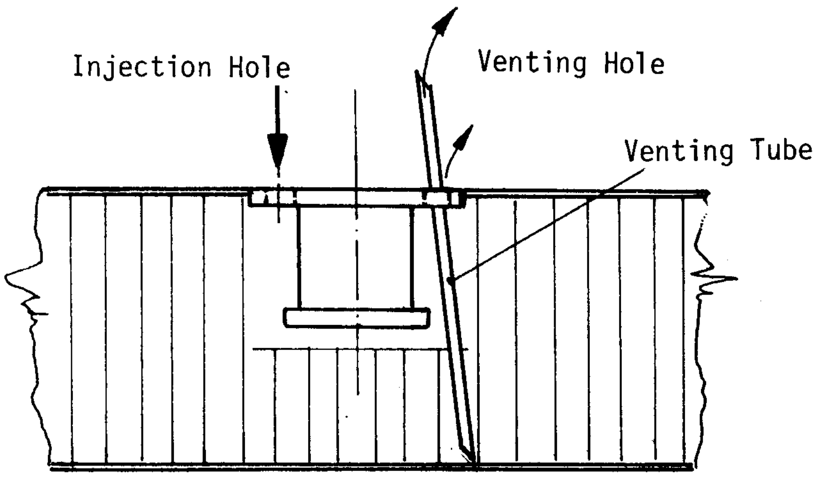


Fig. 3.4: Tube Venting of Non-Perforated Core

3.2.3.3.3 Filling of the Insert Potting Compound

If all the inserts intended for a sandwich structure plate have been prepared in the appropriate manner, injection of the insert potting compound can be carried out according to section 3.2.3.2.3.

The insert potting compound is pressed into one of the two holes in the bonding tabs until it is seen to leave the opposite bore. The appearance of a strand of potting compound about 6 mm long from this outlet shows that the remaining bore cavity and the surrounding honeycomb cells are well filled. The processing times set out in section 3.2.3.2.3 must not be exceeded.

3.2.3.3.4 Cure Cycle

After the inserts have been completely potted into a sandwich structure plate the cure cycle is to be carried out according to section 3.2.3.2.3.

3.2.3.3.5 Final Machining

Inserts which protrude above the surface of the sheet are to be processed by lowering or milling up to the sheet surface -0.03 mm. During this processing the cover sheet must not be damaged. Subsequently the processed surface is to be subjected to chemical oxidizing - Alodine 1200, identification number 1101, according to LN 9368.

The entering of the Alodine 1200 into the insert thread is to prevent.

3.2.3.4 Reference Sample

Reference samples have to be manufactured to enable the success of the potting process to be checked by an insert tear-out strength test.

The sample must consist of the same type of sandwich, insert and potting material as those of the original unit.

The number η of reference samples depends on their criticality

$$n_{standard} = 1 + \frac{Nges}{100}$$

$$n_{safety\ crit} = 2 + \frac{Nges}{10}$$

rounded off to full No. of samples

N_{ges} = Number of inserts of a daily charge

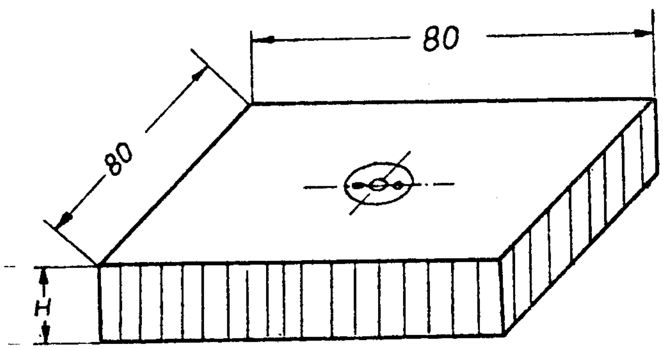


Fig. 3.5: Specimen for Tear-out Strength Testing to Qualify the Potting Process

The potting of the inserts of the reference sample is to be carried out together with the potting of the sandwich structure plate. The reference sample is to be subjected to cure cycle together with the sandwich structure plate. The reference sample is to be identified by the drawing number with an adhesive tape including the information. The vertical tear-out strength is to be determined not earlier than 2 days after the potting. The speed of load application is 2 mm/min.

When the vertical tear-out strength is determined, a tearing-out of the insert of 1 to 2 mm over the cover sheet shall be considered adequate.

The determined tear-out strength is to be documented by a force deflection diagram.

3.2.3.5 Proof Load

A proof load application to flight unit inserts may be required if high reliability requirements apply.

The level of proof load higher than limit load is the subject of current investigation. The initially presented concept is given in Ref. [3].

The need and conditions of proof load control have to be defined in the drawings of the structure.

3.2.3.6 Inspection

The following inspection steps are to be checked, documented and compared with the requirements.

- o Actual diameter of the bores for inserts
- o Actual depth of the bore
- o Check for detachment of cover sheets from the honeycomb core

- o Cleanliness of the bore prior to the potting
- o Inserts shall be flush with the sandwich honeycomb plate with a maximum undershoot of 0.03 mm
- o Perpendicularity of the inserts thread towards the cover sheet maximum deviation ± 0.5°.
- o Filling of injection and venting bore holes with potting compound.

3.2.3.7 Insert Repair

Repair of inserts is occasionally necessary:

- o to replace a destroyed insert
- o to reinforce a destroyed core surrounding the insert
- o to exchange an insert for another (e.g. stronger) one
- o to displace an insert with respect to its location

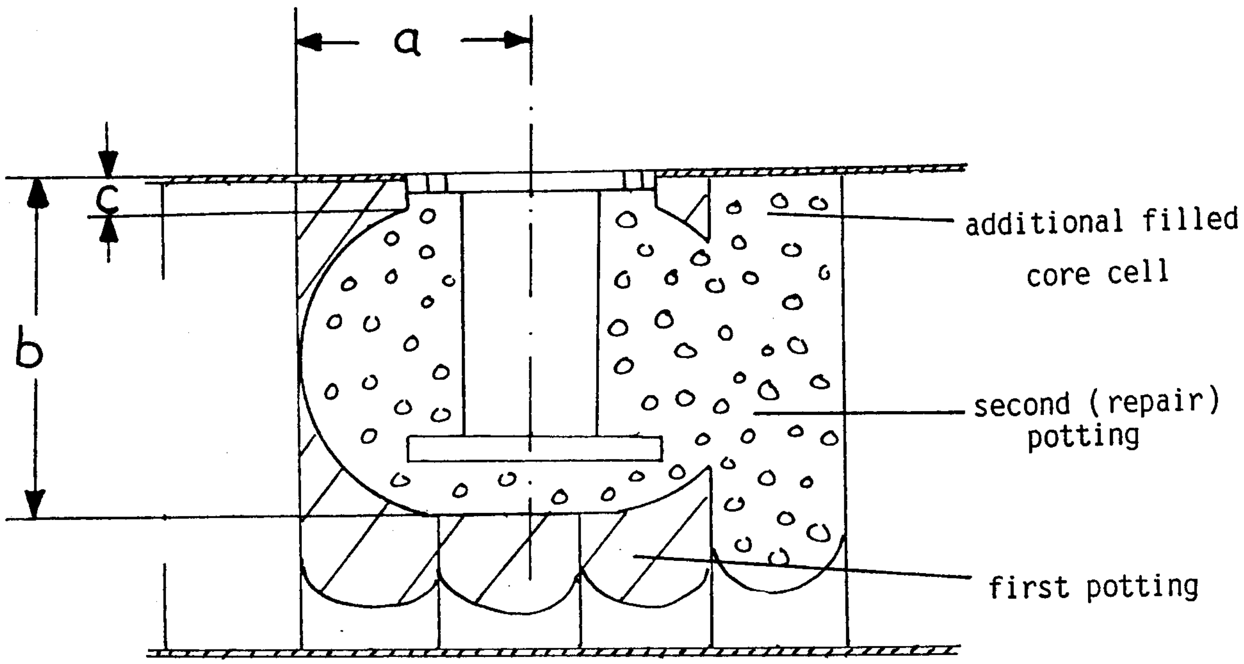
If the surrounding sandwich core and face sheet have sustained no damage, a destroyed insert can reliably be replaced by an insert with the same measurements as follows:

- o Drilling out of the insert to be replaced avoiding excessive heating and too high drilling forces (drill diameter: d_i - 2 mm).
- o Bulgy extension of the bore hole in accordance with Fig. 3.6 by using a milling machine.
- o Extension of the breaks between the first potting and unfilled core cells by using a prickle.
- o Pull off the remained ring of the upper flange of the replaced insert with a pair of tweezers.

- o Reaming up the bore hole within a tolerance of 0 to 0.03 mm.

- o An appropriate amount of insert potting compound is to be filled into the bore hole, enough to comprise the lower flange of the repair insert.

- o The insert is to be inserted in accordance with section 3.2.3.3.2 and filled in accordance with section 3.2.3.3.3.



$$a = r_i + \frac{2}{3} s_c^{\;+1,0}$$

$$b = h_i + 3,0^{+1,0}$$

$$c = 1,5^{+1,0}$$

Fig. 3.6: Geometry of an Insert Repair Potting ($d_{i_{old}} = d_{i_{new}}$; $h_{i_{old}} = h_{i_{new}}$)

If an insert with damaged sandwich area has to be repaired, previous reinforcement of the damaged area is necessary. A suitable method is the injection of liquid resin into each core cell through small bore holes in the face sheet.

For inserts near the edge of a sandwich, the reinjection can be made from the side of the plate.

If a slightly displaced insert shall be exchanged by an insert with larger diameter, or a stronger insert than the potted one is necessary (larger diameter or increased height, see section 2.1.1.3) after drilling out of the old insert remained potting compound of the first potting should be worked adequate as described in Fig. 3.6 to guarantee a positive connection.

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4.0 TESTING

4.1 Incoming Inspection Tests

Incoming inspection tests on materials will be performed normally in accordance with the relevant material specification to guarantee the minimum values, which shall have a probability of being exceeded of 99 %. The additional tests described below are necessary to guarantee or predict the insert strength with more reliability.

The materials of interest are the honeycomb core and the potting resin.

4.1.1 Test of Honeycomb Core

The different core inspection test methods defined in MIL-C-7438F for

- o density
- o compression strength
- o shear strength
- o foil thickness

shall be used to determine actual core properties.

The relationship of insert strength to actual core strength is considered for 2 levels: average and minimum, in detail in section 2.1.1.1.3. (See Fig. 1.2.4, Percentual Deviation of Actual Core Strength from Guaranteed Values.)

4.1.2 Test of Epoxy Resin

In cases where a guaranteed strength of potting resin is required

- o at core densities > 50 kg/m^3
- o at great height of core with partial potting etc.

an incoming inspection by strength testing is recommended.

Suitable test methods are the bending and the tensile test which can be applied alternatively.

Test Method	Standard	Size of Samples	Proposed Acceptance Strength (N/mm^2)
Bending	DIN 53452	3 x 15 x 80 mm	110
Tension	DIN 53455	3 x 20 x 150 mm	60

The acceptance values are valid for pure resins without additives (e.g. microballoons).

4.2 Manufacturing Control Tests

4.2.1 Tests on Insert Reference Samples

The purpose of the test on reference samples is to confirm the faultless performance of the potting process (see section 3.2.3.4 of the insert process specification).

4.2.1.1 Determination of Acceptance Loads

The required acceptance values shall be defined in the design documents. If not differently defined on the drawings, the following criterion shall apply.

Strength values below 80 % of P_{SS} av are to be rejected.

4.2.1.2 Test Conditions and Performance

4.2.1.2.1 Test Sample

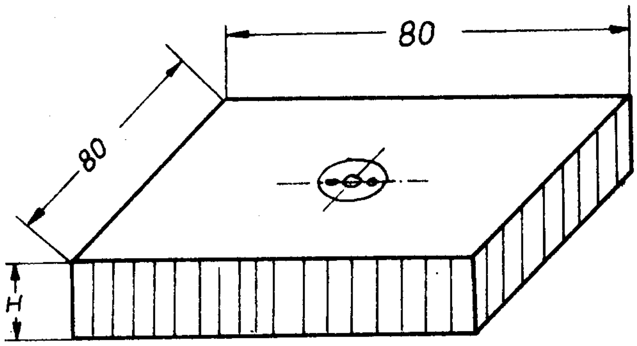


Fig. 4.1: Insert Test Sample for Manufacturing Control Test

The height of the sandwich sample shall be the same as that of the structure concerned and the insert shall be of the same type (see section 3.2.3.4).

4.2.1.2.2 Test Device

See Fig. 4.2.

Recommended for
Insert diameter
D_i < 22 mm

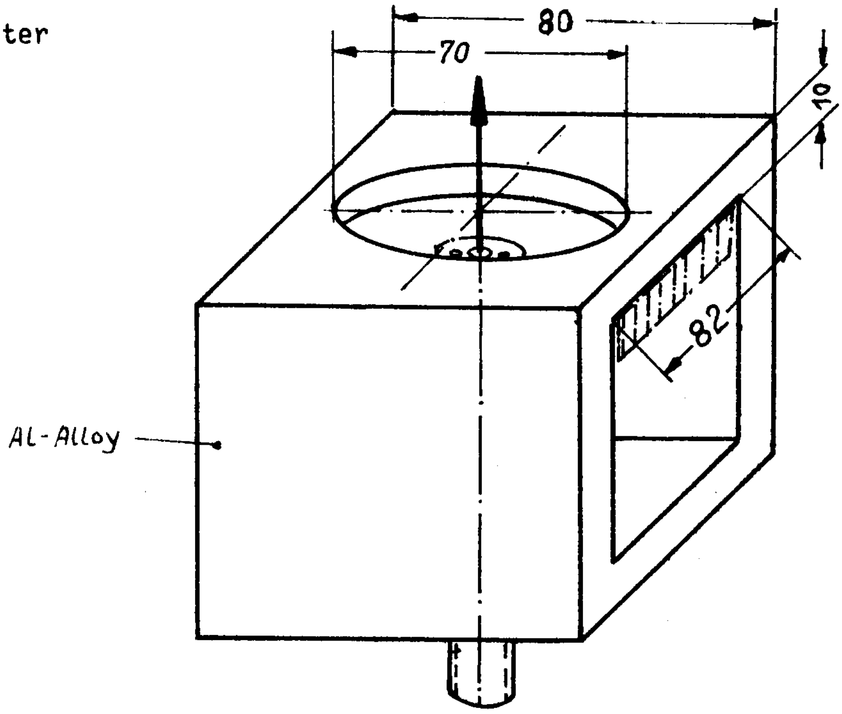


Fig. 4.2: Test Fixture for Insert Tension Test

The test fixture can be a simple frame in which the sample is held and which exposes a free area 70 mm in diameter.

4.2.1.2.3 Test Performance

The test should be performed in an electronically controlled tension test machine which allows the recording of a load-deflection value.

A suitable loading velocity is 2 mm/min.

The deflection should be interrupted after the load maximum has been reached (about 2 mm constant deflection of face sheet). This makes it easier to judge fracture conditions after samples have been taken.

4.2.1.2.4 Test Evaluation

The acceptance conditions are fulfilled if the acceptance value stated in section 4.2.1.1 is reached. Moreover, it is recommended that a sample of potting be cut out so that the quality of potting can be appraised. This should lead to a steady improvement in potting technology.

It is important to discuss any relation between potting failures and bore hole drilling as shown in Fig. 5.1 (Failure of Potting Mass Flow).

4.2.2 Non-Destructive Manufacturing Control Test by X-Ray Radiography

The actual potting condition after manufacturing can be judged by an X-ray view parallel to the axis of an insert.

Items that can be checked are:

1. number of filled cells
2. number of connected cell walls
3. rough estimation of potting height by comparison of grade of absorption with potted inserts which have a known height of potting.
4. large inclusions of air in the potting mass.

The knowledge of the number of connected cell walls is of particular importance for limiting the dispersion of strength values or calculating the actual load-carrying capability of an insert (section 1.2.3.2.1, Effective Potting Radius).

4.3 Development tests

It may be necessary to perform tests to determine insert strength values which are not covered by this Design Handbook.

This may be because the core is of a special type or because a novel method of insert arrangement has been used.

It is advisable to use the experience contained in the Design Handbook's basic test program as documented in References [1] and [2].

5.0 QUALITY ASSURANCE

5.1 General

All standard activities related to QA aspects of controlling materials and manufacturing of sandwich plates and their components (core, facings, adhesive coatings etc.) and of the inserts shall be applicable in general without further reference here.

The typical control activities of the potting process, as described in the next section, are of particular importance because the chemical process of potting is sensitive to failures caused by inaccuracy.

It must be pointed out that the permissible values established in the Handbook are based on a correctly performed process without significant failures.

5.2 Control of Bore Hole Quality

The bore hole must be inspected with respect to the following items:

- The diameter of a bore hole in the facing sheet shall be within a tolerance of 0 to 0.03 mm of the nominal insert diameter.

- The depth of bores in the honeycomb-sandwich structure shall exceed the overall height of the insert by 3 to 4 mm.

- The area surrounding the bore in the honeycomb core shall be free from defects and shall not contain any bent edges of cell walls or dislocated layers of core foil preventing the free flow of the potting resin into open cells.

- Undercutting or detachment of the core from the face sheet caused by mechanical damage or overheating shall not exceed the radius by more than 2 mm.

- The radius of core bore hole shall never be less than the nominal measurements of the insert flanges, which would lead to a reduction of strength below the minimum tolerated values (see Fig. 5.1 No. 4). This may occur if a blunt or damaged punching tube is used or the bore hole drilling and reaming process is insufficient.

- In view of the need to avoid contamination, the application of lubrication or cooling liquid is not admissible.

5.3 Control of the Insert Potting Quality

The potting process has to be protected against failures as listed in Table 5.1 and shown in Fig. 5.1. For failure detection three characteristic methods are applicable:

- the continuous process control step by step
- the strength test on separately manufactured reference samples
- the 100 % - or less - proof load application to all inserts.

As shown in Table 5.1, one of these methods alone guarantees the detection of all failures. Process control seems to cover most failures, however, and is therefore of great importance.

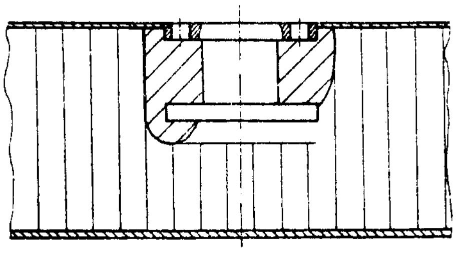
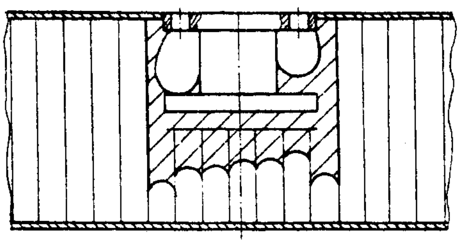
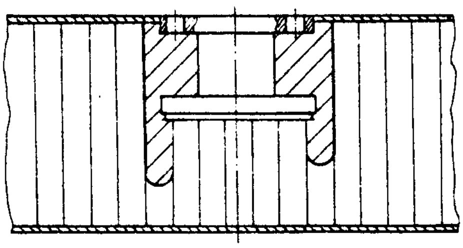
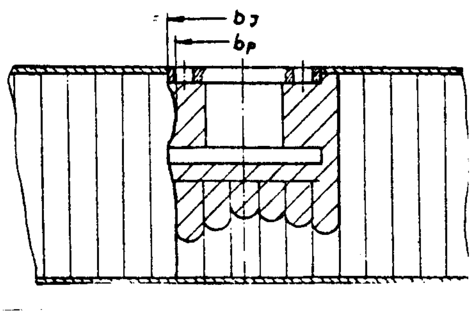
		Indication	Possible Reason
1		Incomplete filling	Too short duration of injection. Unperforated core, too high viscosity
2		Air inclusion underneath insert bore holes	Too low viscosity of potting mass
3		Incomplete filling	Distance between insert bottom and core is less than 3 mm, or cell walls are dislocated
4		Potting radius smaller than insert radius $b_p < b_I$	A damaged or blunt punching tube makes a core bore hole smaller than the nominal insert diameter (see section 3)

Fig. 5.1: Failure of Potting Mass Flow Leading to Strength Degradation

Table 5.1: Failure Effects

Item	Reason of Deviation	Effect of Deviation: strength degradation	Effect of Deviation: total loss 1)	Effect of Deviation: loss at dyn. load	Effect of Deviation: out-gassing	Deviation detectable by: process control	Deviation detectable by: separate test sample	Deviation detectable by: 100 % load control	Remarks
resin	1 ratio of mixing	x			x	x	x	-	The crosses and dashes indicate whether or not deviation cause effects and how they are detectable
	2 insufficient mixing	x			x	x	x		
	3 wrong component	x	x	x	x	x	x	x	
	4 over-storaged	x			x	x	x	-	
adhesion	5 insufficient cleaning	x		x		~	~	~	
	6 contam. after cleaning	x		x		~	~	~	
process	7 bore hole failure	x				x	-	-	
	8 incomplete filling	x	x	x		~ 2)	-	~	
	9 air bubbles (little)	x				x	-	~	
	humidity	x		x		x	-	-	

Explanation of symbols:
x yes
~ eventually
- no

1) tear out by very small load

2) Inspection of bore holes after filling

Table 5.1:
Failure Effects

Consequently, a suitable combination of controlling methods is advisable. The potting process specification (section 3.2) defines a suitable sequence, but other sequences may also be applicable.

5.4 Receiving Inspection Required for Application of Minimum Values

The minimum core shear strength $\tau_{W_{min}}$ and $\tau_{c_{min}}$ may be unacceptably low in view of:

- o minimum foil thickness (density < p_N)
- o very high degree of expansion
- o very low material strength of foils
- o extensive distortion and buckling.

This may seem very conservative, as there is a tendency for

- o density to be even higher than nominal
- o under-expansion due to constraints from the outer border during panel manufacturing.

Therefore, an inspection sequence such as that shown in Fig. 5.2 may be applied with high probability of success. It

- o ensures minimising the additional effort in receiving inspection, and
- o allows for a simple insert selection without extensive analysis.

Leaving the logic via box 4 requires the application of minimum values.

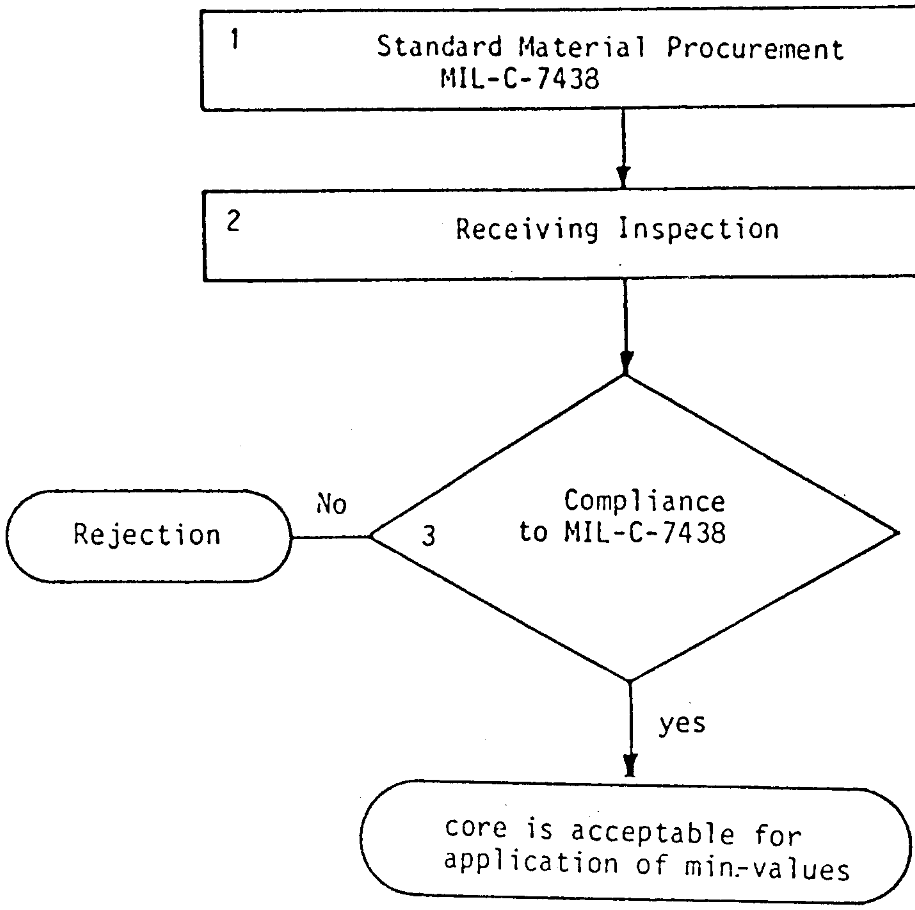


Fig. 5.2: Logic of Receiving Inspection for Honeycomb Core

5.5 Determination of Normalised Density

In order to identify the density under nominal degree of expansion the following inspection sequences have been generated:

1. Cutting of test pieces out of the core material (MIL-C-7438)

2. Weighing of samples

3. Calculation of actual density

4. Determination of actual cell size by counting 10 cells and measuring their overall length in W-direction

5. Calculation of actual degree of expansion by the formula

$$\frac{\text{actual cell size}}{\text{nominal cell size}} \cdot 100\ [\%]$$

6. Determination of the correction factor K_{ex} by using the density expansion diagram of Fig. 5.3, page ..

7. Correction of actual density ρ in order to obtain the normalised density ρ_N

$$\rho_N = K_{ex} \cdot \rho_{act.}$$

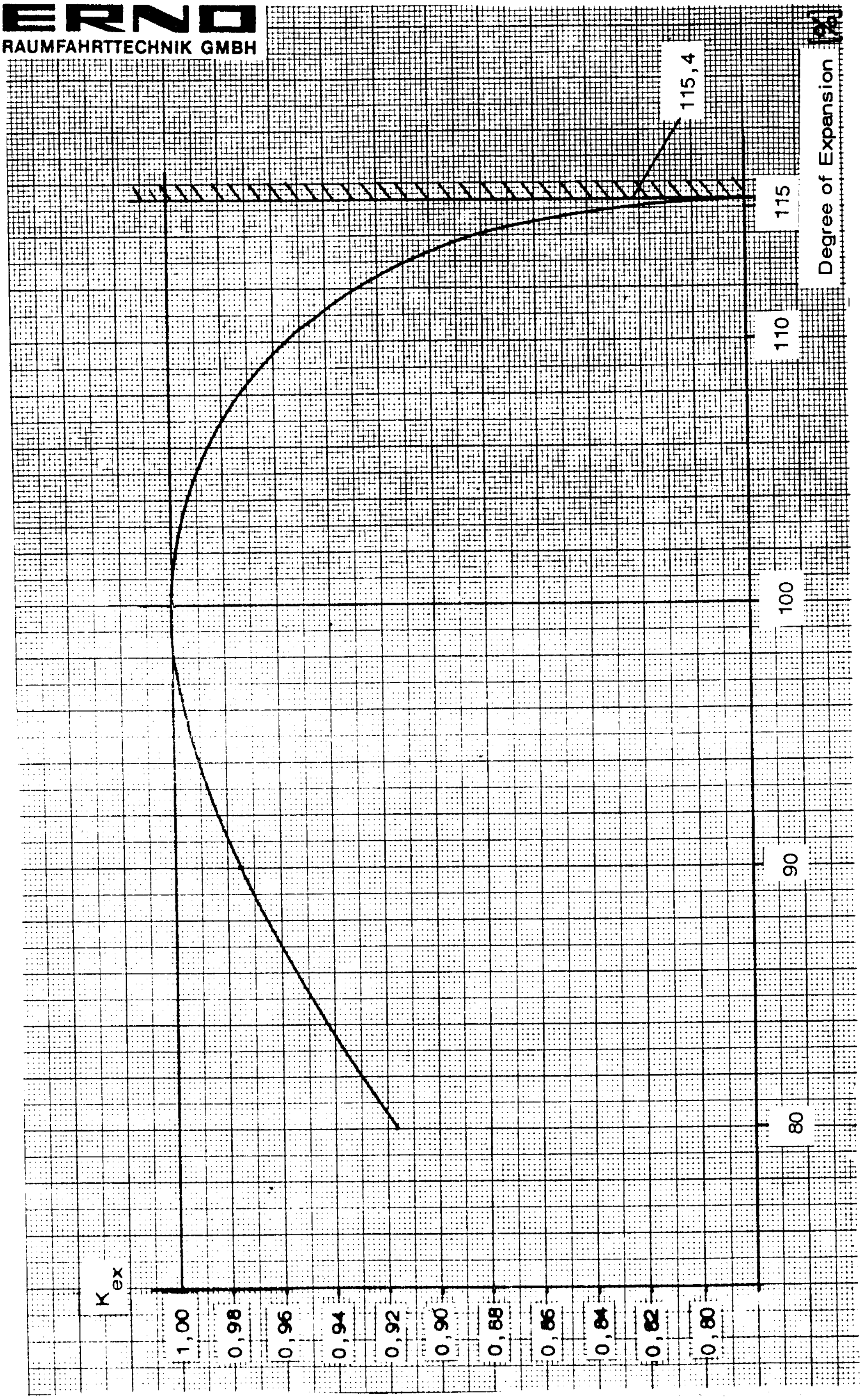


Fig. 5.3: Density Correction Factor Kex for Degree of Expansion

5.6 Documentation and Tracing

The material and process control data should be entered on the data sheet (Fig. 5.4).

In the case of failures or non-conformances, a material review board (MRB) shall be organised.

5.7 Requirements Imposed on the Personnel

The supervisor shall ensure that personnel are familiar with these instructions. Furthermore, the contractor shall ensure that the requirements of this manufacturing instruction manual are observed.

5.8 Work Safety Requirements

In general the safety rules of the employers' liability insurance of fine mechanics and electronics apply as well as the regulations of authorities (UVV 11.2 + VBG 81).

For machines, apparatus and facilities in general, these instructions are governing over other already existing employers' liability insurances.

The safety equipment required for the individual manufacturing steps are to be planned and made available and are to be used by the executing department with which the order has been placed on the manufacture.

The body protecting means which are required during the manufacture are to be used or worn, respectively.

<u>ATTENTION:</u> Resin and hardener may cause skin irritation. Sufficient ventilation is to be provided.

ERNO RAUMFAHRTTECHNIK GMBH	Data Sheet Potting of inserts into sandwich structure with insert potting compound	Sach-Nr	ERNO -227-

Designation of structural component

Drawing number

Type of resin

Hardener

Insert - type number

	Assessment
Checking of the bore diameter	
Checking of the bore depth	
Cleanliness of the bores	
Condition of the honeycomb cores	
Checking for detachment of the cover sheets	
Degreasing of the inserts	

Number of resin compound amount

Temperature / rel. air humidity °C %

Processing time

Cure cycle start: end:

	Assessment
Checking for position of the axis	
Checking for flushness	
Results of the vertical tear out strength	
Post-treatment with Alodine 1200	

Remarks

Manufacturer Department, date, name	Control department, date, name

16

Urheberschutzvermerk nach DIN 34

ERNO 13/4

Fig. 5.4: Material and Process Data Control Sheet

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Appendix A

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ANALYTICAL DETERMINATION OF THE STATIC CAPABILITY OF AN INSERT IN A LARGE SANDWICH PANEL

1.0 LOAD NORMAL TO SANDWICH PANEL

1.1 Fully Potted Insert

The following formulae are based on Ref. [6] and [7]. Their validity has been proven in [1] and [2].

The distribution of the shear stresses in the core of a circular sandwich panel provided with a rigid central and clamped insert submitted to normal load is given by the formula:

$$\tau(r) = \frac{P I_m}{\pi(h+c)I}\left\{\frac{1}{r} - \frac{I_1(\alpha r)}{ab} \times \left[\frac{bK_1(b) - aK_1(a)}{I_1(\alpha a)\,K_1(\alpha b) - I_1(\alpha b)\,K_1(\alpha a)}\right] \cdot \frac{K_1(\alpha r)}{ab}\left[\frac{aI_1(\alpha a) - bI_1(\alpha b)}{I_1(\alpha a)\,K_1(\alpha b) - I_1(\alpha b)\,K_1(\alpha a)}\right]\right\} \quad (1.1)$$

where

$\tau(r)$	=	shear stress in the core at radius r (Fig. 1)
P	=	applied load at insert
c	=	core thickness
h	=	total sandwich thickness = c + f + f'
f,f'	=	facing thicknesses; equal or unequal
a	=	outer radius of panel
b	=	radius of potting = b_p

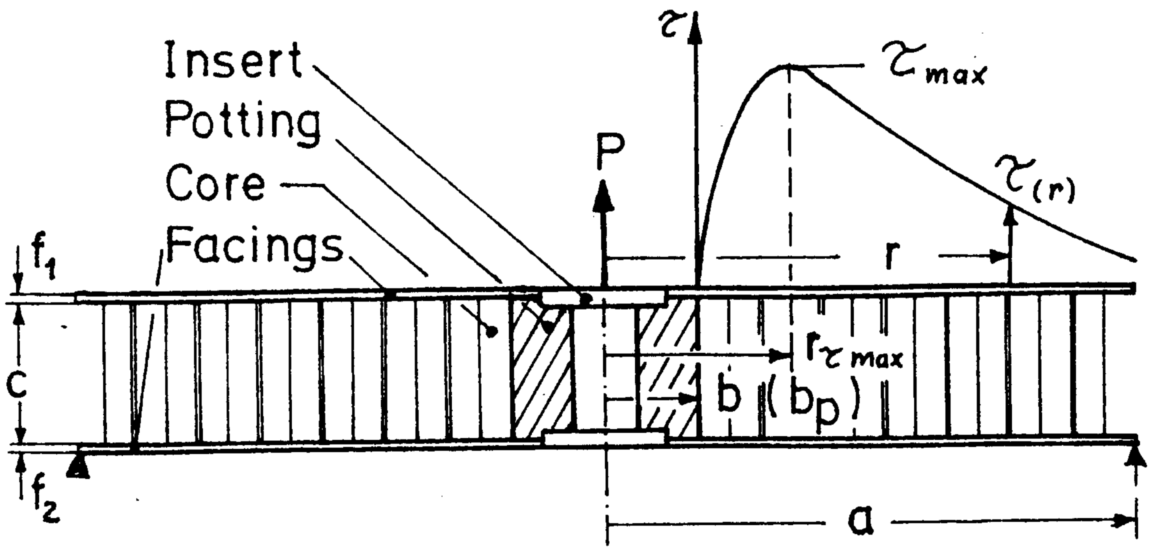

Fig. A1: Fully Potted Insert

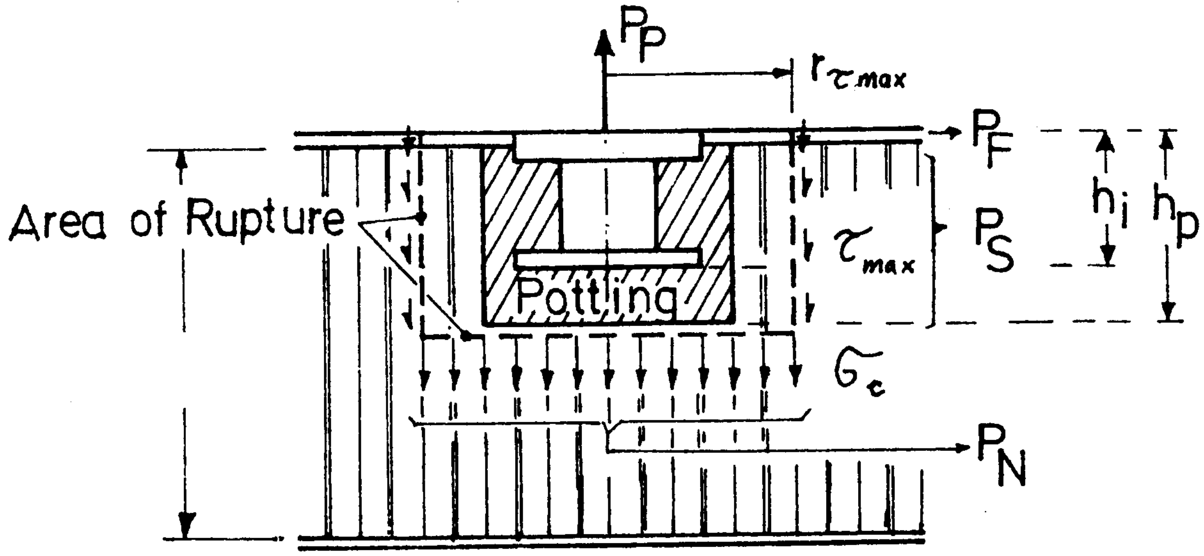

Fig. A2: Partially Potted Insert

I_m = moment of inertia of the panel = $[f.f'(h+c)^2] / [4(h-c)]$

I_f = moment of inertia of both facings = $(f^3+f'^3)/12$

I = $I_m + I_f$

α = $\sqrt{G_c(h-c)I / [Ecff'I_f]}$

G_c = shear modulus of facings

E = $E_f / (1-\nu_f^2)$

E_f = Young's modulus of facings

ν_f = Poisson's ratio of facings

$I_1(x)$, $K_1(x)$ = modified Bessel functions ($x = \alpha r, \alpha a, \alpha b$)

For αr, αa and $\alpha b > 5$ the modified Bessel functions become the exponential functions:

$$I_1(x) = e^x (2\pi x)^{-1/2}$$
$$K_1(x) = -e^{-x}(\pi/2x)^{1/2} \qquad (1.2)$$

Substitution of equation (1.2) into equation (1.1) results in the formula

$$\tau(r) = \frac{PI_m}{\pi b(h+c)I} . K \qquad (1.3)$$

with $$K = \frac{b}{r}\left[1 - \sqrt{r}\,\frac{\sqrt{b}\,(e^{\alpha(r-b)} - e^{-a(r-b)}) + \sqrt{a}\,(e^{\alpha(a-r)} - e^{-\alpha(a-r)})}{\sqrt{ab}\,(e^{\alpha(a-b)} - e^{-\alpha(a-b)})}\right] \qquad (1.4)$$

or $$K = \frac{b}{r}\left[1 - \sqrt{r}\,\frac{\sqrt{b}\,(\sinh\alpha(r-b) + \sqrt{a}\sinh\alpha(a-r)}{\sqrt{ab}\sinh\alpha\,(a-b)}\right] \qquad (1.4a)$$

For $r < a$, a good approximation for K is

$$K = \frac{b}{r}\left[1 - \sqrt{\frac{r}{b}}\,e^{\alpha(b-r)}\right] \qquad (1.5)$$

For f' = f we obtain, with a rearrangement of the previous equations:

$$I_m = f(c+f)^2/2$$

$$I_f = f^3/6$$

$$I = f(c^2/2 + cf + 2f^2/3)$$

$$\alpha = \frac{1}{f}\sqrt{\frac{G_c}{E_f}\, 12\,(1-\nu_f^{\,2})\,\left(\frac{\beta}{2} + 1 + \frac{2}{3\beta}\right)} \qquad (1.6)$$

$$\tau_{(r)} = \frac{P}{2\pi bc}\,\frac{\beta(m+1)}{(\beta^2+2\beta+4/3)}\,K \qquad (1.7)$$

with $\beta = c/f$ (1.8)

For $\beta \geq 10$, i.e. $c \leq 10$ mm and $f \geq 1$ mm, equations (1.6) and (1.7) can be approximated by

$$\alpha = \frac{1}{f}\sqrt{\frac{G_c}{E_f}\, 12\,(1-\nu_f^{\,2})\,(1+\beta/2)} \qquad (1.9)$$

$$\tau(r) = \frac{P}{2\pi bc}\,\frac{\beta}{\beta+1}\,K \qquad (1.10)$$

with an error of less than 0.5 %.

The core shear stress distribution can be expressed by the formula

$$\tau_{(r)} = \tau_{nom} \cdot C^* \cdot K \qquad (1.11)$$

with $\tau_{nom} = P/2\pi bc$ (1.12)

$$C^* = \beta/(\beta+1) \qquad (1.13)$$

$$K = \frac{b}{r}\left[1 - \sqrt{\frac{r}{b}}\, e^{\alpha(b-r)}\right] \qquad (1.5)$$

According to Refs. [1] and [4], the position of the maximum core shear stress is

$$r_{\tau\ max} = b/[1-e^{c_2(\alpha b)^n}] \qquad (1.14)$$

with c_2 = -0.931714

and n = 0.262866

The value of $r_{\tau\ max}$ has to be fed into equation (1.5) in order to obtain K_{max} which is to be introduced into equation (1.11) in order to obtain

$$\tau_{max} = \tau_{nom} \cdot C^* \cdot K_{max} \qquad (1.15)$$

If τ_{max} attains the core shear strength τ_{crit}, the insert capability is given by

$$P_{crit} = (2\pi bc\ \tau_{c\ crit}) \ / \ (C^* K_{max}) \qquad (1.16)$$

Equation (1.16) is valid for tensile and compressive load.

1.2 Partial Potting

a) Partial Potting in Aluminium Core

In the case of a partially potted insert in aluminium core, the load P_p applied to the insert/sandwich system consists of 3 parts (Fig. A2):

P_F = load part carried by the upper facing

P_S = load part carried by shear stresses in the core around the potting

P_N = load part carried by normal stresses in the core underneath the potting

These load parts are given by the formula

$$P_F = (P_{\tau\,max} - 2\pi r_{\tau\,max} \cdot c \cdot \tau_{max}) / 2 \qquad (1.17)$$

$$P_S = 2\pi r_{\tau\,max}\, h_p\, \tau_{max} \qquad (1.18)$$

$$P_N = \pi r^2_{\tau\,max}\, \sigma_c \qquad (1.19)$$

with $P_{\tau\,max} = 2\pi\, b\, c\, \tau_{max} / (C^* K_{max})$

= load of a fully potted insert corresponding to τ_{max} which becomes P_{crit} for $\tau_{max} = \tau_{c\,crit}$ according to equation (1.16)

$r_{\tau\,max}$ = distance of maximum core shear stress from insert centre according to equation (1.14)

σ_c = normal stresses in the core underneath the potting which are tensile stresses σ_{ct} for tensile load, and compression stresses σ_{cc} for compressive load.

h_p = height of potting

For an insert with a height of h_i the minimum potting height required is

$$h_{p\,min} = h_i + 7 \text{ mm whatever the core height c.}$$

The typical value of h_p depends on the core height according to

$$h_{p\,typ} = h_{p\,min} + A \text{ tgh } (c - h_{min})/h_{p\,min} \qquad (1.20)$$

with $A = 5$ for cell size S_c = 4.8 mm (3/16" core)

and $A = 2.5$ for cell size S_c = 3.2 mm (1/8" core)

Equation (1.20) is only valid for partial potting, i.e. for $c > h_i + 7$ mm.

P_S is limited by the core shear strength $\tau_{c\ crit}$.

P_N is limited by the tensile strength $\sigma_{c\ crit\ t}$ of by the compressive strength $\sigma_{c\ crit\ c}$ of the core.

Theoretically, for a linear behaviour, the two failure modes (shear rupture and tensile or compressive rupture of core) do not occur together. But in reality, owing to non-linearity effects, the shear strength and the tensile or compressive strength of the core are attained together.

Therefore the components of the critical load of partially potted inserts are

$$P_{F\ crit} = (P_{crit} - 2\pi r_{\tau\ max}\ c\ \tau_{c\ crit})/2 \qquad (1.17a)$$

$$P_{S\ crit} = 2\pi\ r_{\tau\ max}\ h_p\ \tau_{c\ crit} \qquad (1.18a)$$

$$P_{N\ crit} = \pi\ r^2_{\tau\ max}\ \sigma_{c\ crit} \qquad (1.19a)$$

with $\sigma_{crit} = \sigma_{c\ crit\ t}$ for tensile load

$\sigma_{crit} = \sigma_{c\ crit\ c}$ for compressive load

Thus the capability of a partially potted insert is given by

$$P_{p\ crit} = \tfrac{1}{2}P_{crit} + \pi . r_{\tau\ max} \cdot (2h_p - c) \cdot \tau_{c\ crit} + \\ + \pi\ r^2_{\tau\ max} \cdot \sigma_{c\ crit} \qquad (1.21)$$

b) Partial Potting in a Non-Metallic Core (e.g. NOMEX, GFRP)

Due to insufficient ability of the rigid non-metallic cores to distribute stress concentrations by local deformations the insert capability increases only slightly for constant h_p with increasing core height c.

The stress concentration in case of the partially potted insert is considered as conservatively covered by the formulation:

$$P_{ss_{pp}} = P_{ss_{fp}} \cdot \frac{1}{K_{t_{pp}}} \tag{1.22}$$

with $P_{ss_{pp}}$ = Permissible load of a partially potted insert ($h_p < c$)

$$P_{ss_{pf}} = \frac{2\,\pi \cdot b_p \cdot c \cdot \tau_{c\ crit}}{C^* \cdot K_{max}} \tag{1.16}$$

= Permissible load of a fully potted insert ($h_p = c$)

$$\frac{1}{K_{t_{pp}}} = \left(\frac{h_p}{c}\right)^{0.62} \tag{1.23}$$

= Stress concentration factor

For $c > 2.5\ h_p$ the permissible load of a partially potted insert in a non-metallic core is considered quasi-linear.

1.3 Potting Failure for Inserts Under Tensile Loading

For a partially potted insert in a heavy core with a high tensile strength, a rupture of the potting resin underneath the insert may occur, but only under tensile load.

a) Partially Potted Inserts in a Heavy Aluminium Core

As in Section A1.2, the load P_R applied to the insert/sandwich system consists of three parts:

P_F = part of load carried by the upper facing sheet

$$= \tfrac{1}{2}(P_{\tau\ max} - 2\pi r_{\tau\ max} \cdot c \cdot \tau_{max}) \tag{1.17}$$

P_{SR} = part of load carried by shear stresses in the core around the potting over the insert height

$$= 2\pi r_{\tau\ max} \cdot h_i \cdot \tau_{max} \tag{1.18b}$$

P_{NR} = part of load carried by normal stresses in the resin underneath the insert

$$= \pi . b_R^2 \cdot \sigma_R \tag{1.19b}$$

with

h_i = insert height

b_R = real potting radius (which is not identical to the equivalent potting radius b in Section A1.1; see Section 1.2.3.2.2),

σ_R = tensile strength in the potting resin

$$P_R = P_F + P_{SR} + P_{NR} \tag{1.24}$$

P_{NR} can also be expressed by the formula:

$$P_{NR} = P_F + (P_R - 2P_F)\,(c-h_i)/c$$
$$= P_F(1-2\psi) + P_R.c$$

with

$$\psi = (c-h_i)/c \qquad (1.25)$$

$$P_F = P_{NR}/(1-2\psi) - P_R\,\psi/(1-2\psi) \qquad (1.26)$$

P_{SR} can be expressed in terms of P_R by means of equations (1.16) and (1.22):

$$P_R = 2\pi.b.c\,.\,\frac{\tau_{max}}{C^*.K_{max}}$$

$$2\pi\tau_{max} = P_R\,.\,C^*\,.\,K_{max}\,.\,\frac{1}{b.c}$$

$$P_{SR} = 2\pi.r_{\tau\ max}\,.\,h_i\,.\,\tau_{max}$$

$$P_{SR} = P_R\,.\,C^*\,.\,K_{max}\,.\,r_{\tau\ max}\,.\,\frac{h_i}{b.c}$$

If equations (1.26) and (1.27) are introduced into equation (1.24), the critical insert load under which the potting resin fails is given by

$$P_{R\ crit} = 2P_{NR\,crit}\,.\,\frac{\left(\dfrac{1-\psi}{1-2\psi}\right)}{\left[\dfrac{1-\psi}{1-2\psi} - \dfrac{C^*.K_{max}.r_{\tau\ max}.h_i}{b.c}\right]}$$

with

$$P_{NR\ crit} = \pi b_R^{\,2}\,\sigma_{R\ crit} \qquad (1.29)$$

$\sigma_{R\ crit}$ = tensile strength of potting resin

b) Partially Potted Inserts in a Heavy Non-Metallic Core

As described in section A.1.2.b, the permissible load $P_{ss_{pp}}$ applied to the insert/sandwich system is determined:

$$P_{ss_{pp}} = P_{ss_{fp}} \cdot \frac{1}{K_{t_{pp}}} \qquad (1.22)$$

with $P_{ss_{fp}}$ = Permissible load of a partially potted insert ($h_p < c$)

$$P_{ss_{pf}} = \frac{2\pi \cdot b_p \cdot c \cdot \tau_{c\,crit}}{C^* \cdot K_{max}} \qquad (1.16)$$

$$\frac{1}{K_{t_{pp}}} = \left(\frac{h_p}{c}\right)^{0.62} \qquad (1.23)$$

and

$P_{ss_{pp}}$ is quasi constant for $c > 2.5\ h_p$.

The potting failure of an insert in a non-metallic core is considered to occur in case of:

$$P_{ss_{pp}} = \pi \cdot b_R^2 \cdot \sigma_{R\,crit}$$

with

b_R = real potting radius

$\sigma_{R_{crit}}$ = tensile strength of potting resin

1.4 Additional Criterion for Compressively Loaded Inserts in Sandwich Panels with Thick Facing Sheets

Under *compressive* load, the upper facing sheet does not contribute to the insert capability if the thickness of the aluminium facing sheets exceeds 0.6 mm. this is due to tensile rupture of the bonding between core and upper facing sheet in the vicinity of the insert.

a) Inserts in Aluminium Core

For this case, the insert capability has to be reduced according to

$$P_{crit\ c} = \frac{P_{crit}}{2} + \pi r_{\tau\ max}\ c\ \tau_{c\ crit} \qquad (1.30)$$

for fully potted inserts (P_{crit} according to equation (1.16)) and

$$P_{p\ crit\ c} = 2\pi r_{\tau max}\ h_p\ \tau_{max} + \pi r^2_{\tau\ max}\ \sigma_{c\ crit\ c} \qquad (1.31)$$

for partially potted inserts.

b) Inserts in Non-Metallic Core

For this case the insert capability has to be reduced according to

$$P_{crit\ c} = \frac{P_{crit}}{2} + \pi r_{\tau\ max}\ c\ \tau_{c\ crit} \qquad (1.30)$$

for fully potted inserts (P_{crit} according to equation (1.16)) and

$$P_{crit\ c} = \frac{P_{crit}}{2} + \pi r_{\tau\ max}\ c\ \tau_{c\ crit} \cdot \frac{1}{K_{t_{pp}}} \qquad (1.23)$$

with:

$$\frac{1}{K_{t_{pp}}} = \left(\frac{h_p}{c}\right)^{0.62} \qquad (1.24)$$

for partially potted inserts.

1.5 How to Use the Formula

If the insert height h_i or the potting height h_p coincide with the core height c, the insert is really fully potted. The insert capability P_{crit} can be determined by means of the equations set out in section A1.1, especially equations (1.9), (1.13), (1.14), (1.5) and (1.16) (or (30) for compression load and thick facing sheets).

If the insert height h_i and, especially, the potting height h_p are smaller than the core height c, two values hvae to be determined:

- o capability P_{crit} of an identical insert system which is assumed to be fully potted, by means of the equation mentioned above

- o capability $P_{p\ crit}$ of the partially potted insert by means of the supplementary equations (1.21) and (1.22) of section A1.2 or (1.31) for compression load and thick facing sheets.

The lower value of insert capability is relevant, If $P_{crit} < P_{p\ crit}$, the partially potted insert has the behaviour of a fully potted insert. If $P_{p\ crit} < P_{crit}$, the partially potted insert has the behaviour of a really partially potted insert.

In addition one should make sure that no tensile rupture occurs in the potting resin. This has to be checked by means of the supplementary equations (1.22), (1.24), (1.28) and (1.29).

The potting resin fails if simultaneously $P_{Rcrit} < P_{crit}$ and $P_{Rcrit} < P_{p\ crit}$.

Finally it is pointed out that the equations mentioned, especially the fundamental equation (1), are valid independently of the outer boundary conditions of the panel, provided that the panel radius a is great enough. A sufficient accuracy, specially concerning the critical area near the insert where τ_{max} occurs, is generally given if a > 2b. The equations are only valid for a clamped insert, which is the usual case.

1.6 Reliability

The comparison of these theoretical formulas with the test results of Ref. (2) gives the following correlation coefficient $CC = P_{crit\ test}/P_{crit\ theory}$:

CC = 0.993 with a standard deviation of G = 0.059
for fully potted inserts and inserts behaving like fully potted inserts under tensile and compressive load

CC = 1.043 with a standard deviation G = 0.52
for partially potted inserts under tensile load

CC = 0.988 with a standard deviation G = 0.072
for partially potted inserts under compressive load

To ensure a reliability of 99 % the theoretical values should be multiplied by the reliability coefficient RC.

a) Inserts under Tensile Loading in Metallic Core

o Minimum values

- $RC = 1.172 - 0.0063 \cdot h_c - 0.2641 \cdot f$
  for the inserts in the perforated aluminium core

- $RC = 0.91$
  for the other types of core (e.g. unperforated aluminium, NOMEX and GFRP core)

o Average values

- $RC = 1.207 - 0.00544 \cdot h_c - 0.2088 \cdot f$
  for the inserts in the perforated aluminium core

- $RC = 1$
  for other cores

b) Inserts under Compressive Loading in Metallic Core

- o Minimum values
  - RC = 0.89
    for inserts in all types of core

- o Average values
  - RC = 1
    for inserts in all types of core

Appendix B

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Standards of Inserts

1) ENN 366
2) ENN 379
3) ENN 386
4) ENN 398

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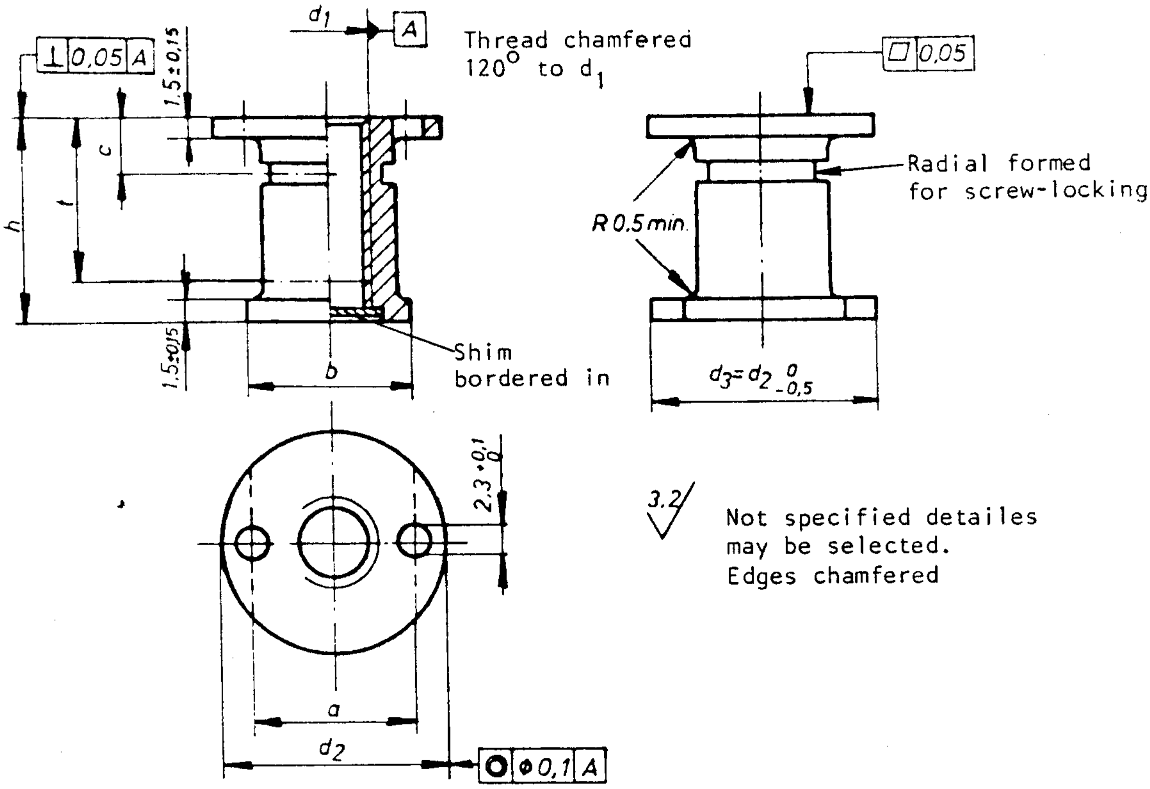
Werknorm

Draft November 1981

ERNO RAUMFAHRTTECHNIK GMBH	Inserts for sandwich constructions, closed, screw-locking	ENN 366E

Einsätze für Wabenkernverbunde, geschlossen, schraubensichernd

Dimensions in mm



3,2 Not specified detailes may be selected. Edges chamfered

Designation of an insert of material 3.1354-T81 (code letter B) with thread size d_1 = M4 (size No. 04) and h = 12 mm:

Insert ENN 366 B 04-12

Size No.	Thread d_1	a ± 0,2	b ≈	c ≈	d_2 0 -0,05	Screw penetration t min.	max.	preferred hole dia. for d_2 +0,03 0	h ± 0,2 1) 9	12	15	18
									Mass Kg/1000 pieces max.			
03	M3	9,3	10,2	3	14	5	h-1	14	1,42			
04	M4	9,3	10,2	3	14	6		14	1,51	1,82		
05	M5	9,3	10,2	3	14	6,5		14	-	1,6		
06	M6	11,8	13,2	3,5	17	7,5		17	-		3	

1) Other heights by agreement with the manufacturer

Continuation page 2

Old issue: 02.76

Change November 1981: Complete revised

Bearb.: 7.12.81 Manke
Gepr.: Ha

ERNO 186/1

Material: -3.1354-T4, Code letter A (not for new design)
-3.1354-T81, Code letter B

Surface treatment for material:

3.1354-T4: - 1101 per LN 9368 (code letter C, add after height h)

- 2002 per LN 9368, colour: yellow

3.1354-T81: - 2100.1 per LN 9368 and for thread Apiezon H, colour: grey

Thread: per LN 9368 Part 2, tolerance 4H5H
per LN 9368 Part 1 and 6

Technical specification: per DIN 65192

Application: Before manufacturing according to this standard, the manufacturer has to clarify patent-law. Only to be used in connection with screws with thread tolerance 4h6h without lubrication.

Remarks: Adhesive tabs have to be delivered for each insert per NAS 1837.

Manufacturer: Shur-Lok

Werknorm October 1983

MBB ERNO
ERNO Raumfahrttechnik GmbH

Inserts

with floating and removable nut
screw-locking

ENN
379E
Part 1

Einsätze mit beweglicher und auswechselbarer Mutter, schraubensichernd

Dimensions in mm

Figure 1 - Insert assembly (A) ②

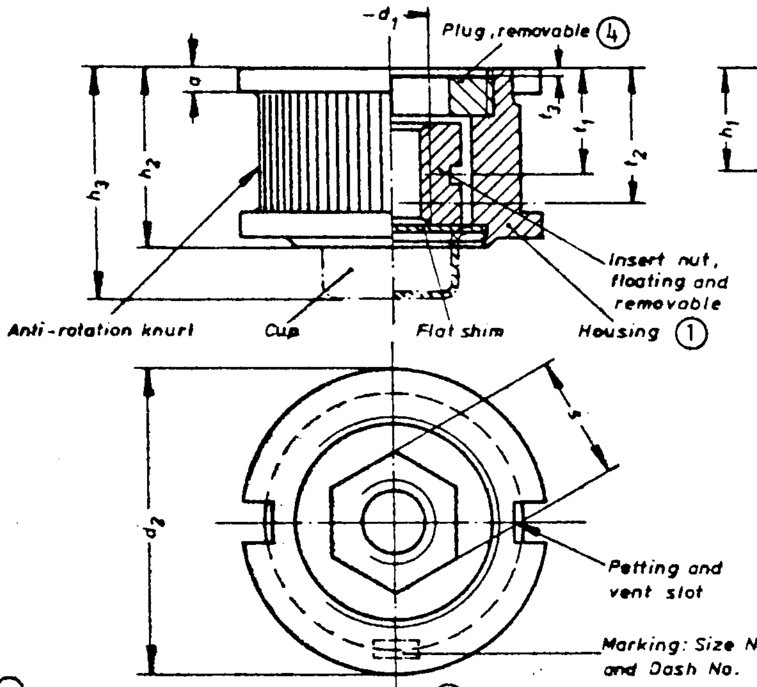
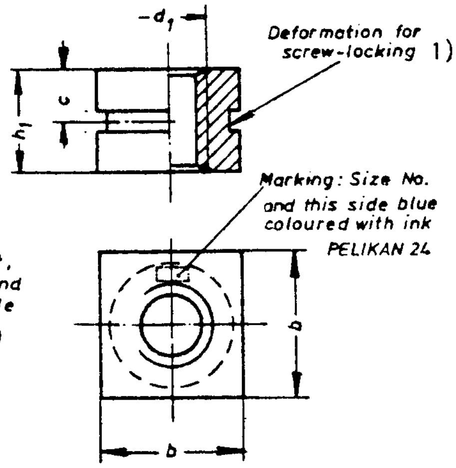


Figure 2 - Insert nut (N) ③



Not mentioned details shall be selected by the manufacturer.

① Example of an insert without nut (Dash) Size No. 06 and Dash No. -1:
Insert ENN 379-06-1

② Example of an insert assembly (A) Size No. 06 and Dash No. -1:
Insert ENN 379A06-1

③ Example of an insert nut (N) with Size No. 06:
Insert ENN 379N06

④ Example of a plug (P) for Size No. 04 and 05 (No. 45):
Insert ENN 379P45

Size No.	a max.	b ±0,25	c 1) min.	Thread d_1 LN 9163	d_2 0 -0,13	h_1 ±0,25	s +0,08 0	t_1 min.	t_3 +0,33 0	Radial floating in all Directions min.	Installation hole diameter +0,13 0
04	2,1	7,9	2,9	M4-4H6H	19	5,8	6,35	6,7	0,05	0,8	19
◣05	2,1	7,9	2,9	M5-4H6H	19	5,8	6,35	6,7	0,05	0,8	19
06	2,1	9,5	3,7	M6-4H5H	22,2	7,5	7,9	8,1	0,20	0,8	22,2

Size No.	Dash No.-1, with flat shim			◣ Dash No.-2, with cup			Plug		Mass kg/1000 pieces (Assy.) ≈
	h_2 +0,76 0	screw penetration t_2 min.	screw penetration t_2 max.	h_3 +0,76 0	screw penetration t_2 min.	screw penetration t_2 max.	Thread UNJEF	No.	
04	10,7	9	10	15,7	9	15,4	.500-28	45	5,8
05	10,7	9	10	15,7	9	15,4	.500-28	45	4,5
06	12,7	10,2	11,7	17,8	10,2	17,4	.625-24	60	9,6

Remarks: ◣ for preferred use 1) Can be determined by the manufacturer

Continuation page 2

MBB ERNO

Bearb 9.2.76 Monke
Gepr

330.30.38

Normenstelle

ERNO 186/1

Old issue: 2.76 6.76 2.77 3.77 5.78 3.78 11.78 07.79 10.79 08.80 07.82

Change October 1983: Values for dimension t_2 have been changed

Page 2, ENN 379 E Part 1

Material:	Housing and Plug - 2024-T62	Finish:	Anodized per MIL-A-8625, Type I, Class 1,
	Insert nut - 2024-T6 or -T62		
	per QQ-A-225/6		Thread of Insert nut thin coated with lubricant type Apiezon H,
	Cup and Flat shim- 6061-0		Chromated per MIL-C-5541, Class 1A
	per QQ-A-250/11		

Procurement Specification: ENN 379 Part 2

Remarks: An adhesive-backed installation tab SLT 600 (NAS 1837) shall be furnished with each insert assembly.

Only use in connection with screws with thread tolerance 4h6h without lubricant.

Torque for plugs: For Size-No. 04 and 05 = 5 Nm and Size-No. 06 = 7 Nm

Manufacturer: For housing and plug-SHUR-LOK International, S.A. Belgium.

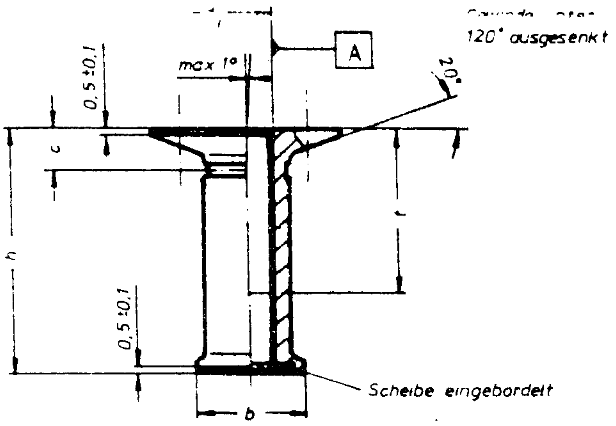
For insert nut -Gebr. Wagschal, D-2804 Lilienthal

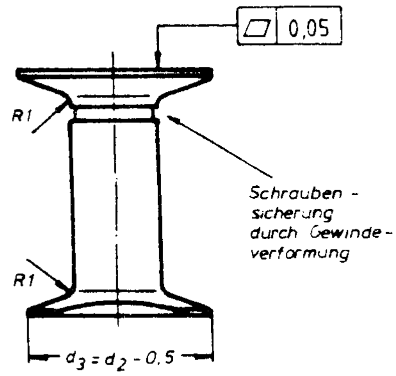
November 1976

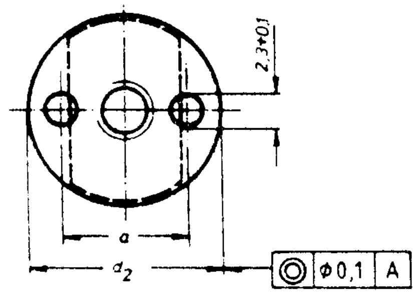
ERNO RAUMFAHRTTECHNIK GMBH	**Befestigungseinsätze** für Kernverbundbauteile geschlossen, selbstsichernd	ENN 386
		Vornorm

Closed inserts for sandwich structures, self-locking

Maße in mm







Nicht angegebene Einzelheiten sind zweckentsprechend zu wählen

Kanten gebrochen

$R_a \leq 3,2 \mu m$

Bezeichnung eines Befestigungseinsatzes aus Werkstoff 3.1354.4 (Kennbuchstabe A) mit Gewinde d_1 = M4 (Kennzahl 04) und Höhe h = 12 mm, mit Oberflächenbehandlung 1101 (Kennbuchstabe C):

Einsatz ENN 386 A04-12 C

Kennzahl	Gewinde d_1	a ± 0,2	b +0,2 / 0	c ≈	d_2 0 / -0,05	Einschraubtiefe t min.	Einschraubtiefe t max.	Loch-Φ für d_2 +0,03 / 0	Höhe h ±0,2: 9	12	15	18	21	24
									Masse in kg/1000 Stück ≈					
03	M3	9,3	8	3	14	5	h-1	14						
04	M4	9,3	8	3	14	6	h-1	14	1					

TK 6 Normensteile

Werkstoff: 3.1354.4 (2024 T 4), Kennbuchstabe A

Oberfläche: 2002, Kenn-Nr nach LN 9368 (MIL-A-8625 Type II Class 2), ohne Kennbuchstabe.
1101, Kenn-Nr nach LN 9368, Kennbuchstabe C.

Fortsetzung Seite 2

Bearb. 23.11.76 H. Schallbuchmeister
Gepr. Marke Kahn

330.30.35

ERNO 186/1

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Werknorm

February 1985

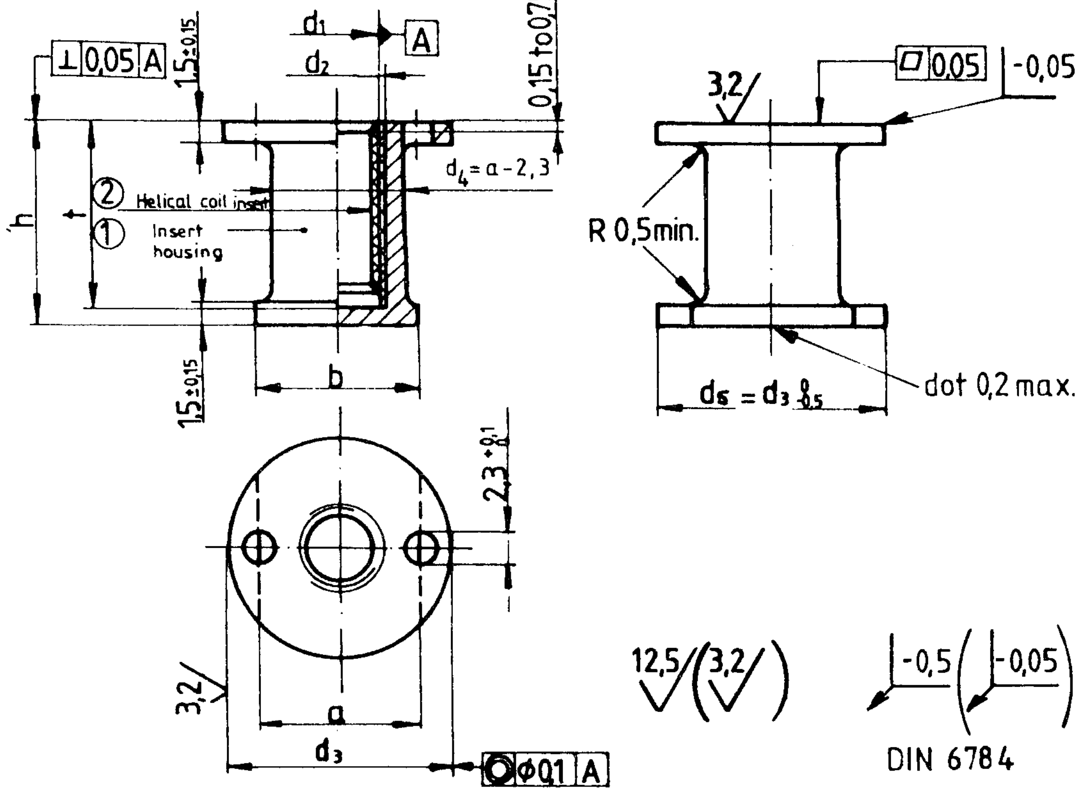
MBB ERNO	**Inserts** for sandwich constructions, closed, with screw-locking helical coil insert (Heli Coil ®)	ENN 398E

Supersedes ENN 366

Old issue: 07.84 08.84 11.84

1 Dimensions and Designation

Dimensions in mm



Designation of an insert with thread size M4 (Size No. 04) and heigth h = 12 mm:

Insert ENN 398-04-12

Thread			a $+0,2$	b $\approx$	d_3 0 $-0,05$	Screw penetration t		h + 0,2			Required Helical Coil Insert
Size No.	d_1	d_2				min.	max.	9	12	15	
								Mass kg/1000 pieces max.			
03	M3	Eg M3	9,3	10,7	14	4,5	h -0,5				LN9499-01045
04	M4	Eg M4	9,3	10,7	14	6		1,6	1,8		LN9499-02060
05	M5	Eg M5	11,9	13,2	17	7,5		-	3,1		LN9499-03075
06	M6	Eg M6	11,9	13,2	17	9		-	3,1		LN9493-04090

1) See page 2

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Continuation Page 2

Revision February 1985: Final status of standard

ERNO 186/2

Bearb. Franz Stöver 12.09.83

Gepr. Manke

MBB ERNO Normenstelle

330.30.36

2 **Material:**
① Insert housing, 3.1354 T351 or T8511 acc. to Werkstoff-Handbuch der Deutschen Luftfahrt

② Helical Coil insert, 1.4301

3 **Surface treatment:**
① Insert housing, 2100.1 LN 9368 Part 1 and 4

② Helical Coil insert, 1200 LN 9368 Part 3

4 **Thread:**
① d_2 (tapped thread) acc. to LN 9499 Part 1

② d_1 acc. to LN 9163 Part 2, Tolerance 4H5H acc. to LN 9163 Part 1 and 6

5 **Installation:** acc. to LN 9499 Part 2

6 **Technical Specification:** DIN 65193

7 **Manufacturer:**

- Gebr. Wagschal D-2804 Lilienthal, for the complete insert
- Böllhoff D-4812 Brackwede, for the Helical coil insert

8 **Remarks:**

- Adhesive tabs for installation/molding according to NAS 1837, or ENN 806
- The inserts have to be used with uncoated and unlubricated titanium bolts with thread tolerance 4h6h only to meet the required 15 cycles of repeated installation.