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TECHNICAL
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XRS 001

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Respiratory protective devices — Human factors —

XRS™ scale:

Breathing comfort classification of a mask from breathing resistance

Appareils de protection respiratoire — Facteurs humains —
Échelle XRS : Classification du confort respiratoire d'un masque à partir de la résistance respiratoire

Reference number
XRS 001:2026(E)

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Foreword

XALPES LLC is an independent organization engaged in applied research, product development and technical validation, established in Austin, Texas. This document was prepared by its Test Laboratory Division, which carries out performance characterization and qualification work on filtering media and filtering assemblies.

Attention is drawn to the fact that this document is not a standard. It does not originate from any national or international standards body, is not the product of any formal consensus process and has no regulatory status. It constitutes a proprietary technical reference document, published under the sole responsibility of XALPES LLC, and adopts the presentation conventions of international standards for the sole purpose of facilitating its reading, citation and scrutiny by third parties.

This document does not replace any existing standard and in no way modifies its application. It addresses a quantity — breathing comfort — that current normative reference documents do not grade, and it does so by relying explicitly on the values that those reference documents establish. Clause 6 sets out in detail the relationship between this document and the normative state of the art.

Attention is also drawn to the possibility that some of the elements of this document may be the subject of intellectual property rights. XALPES LLC shall not be held responsible for identifying any or all such property rights or for giving notice of their existence.

This first edition constitutes the founding version of the reference document. It is complete with regard to the construction of the scale, its physical basis and its documentary verification, but the experimental validation on a human panel described in Clause 14 remains to be carried out. The success criteria and conditions of refutation for that validation are stated in advance, in Clauses 14 and 15 respectively.

A list of the documents cited is given in the Bibliography.

This edition is published openly and explicitly invites criticism. XALPES LLC solicits comments from any competent person on the position of the thresholds, on the assumptions of the model, on the estimated values identified as such and on the validation protocol. A reference document whose criteria of refutation are stated in advance has nothing to gain from discretion: it gains from being examined.

Users should address any feedback, any challenge to a threshold or any proposal of new data to XALPES LLC, at contact@xalpes.com.

Introduction

A respiratory protective mask is designed to stop particles or gases. This function necessarily imposes a resistance to the passage of air, which the wearer must overcome with every inhalation and every exhalation. The design of a mask is therefore, in its very principle, a trade-off between filtration performance and a constraint imposed on breathing.

International normative reference documents rigorously govern the first term of this trade-off. They classify masks by their filtration efficiency, and they bound breathing resistance by ceilings attached to each class. These ceilings are safeguards: they delimit what is physiologically tolerable, not what is comfortable.

The second term of the trade-off is therefore not graded. No reference document today makes it possible to state that one mask is more comfortable than another, or for how long it can be worn without discomfort. This absence has two consequences. For the designer, it deprives the trade-off of any quantified criterion on the comfort side. For the end user, it leaves unanswered the question actually being asked, which is not that of the filtration class but that of the tolerable wearing time.

This document fills that gap. It establishes a six-level scale, known as the XRS™ scale, which translates a physical quantity measurable on a bench — specific resistance, defined in 3.1 — into a comfort qualification and a breathing endurance. Each of the six thresholds is anchored to an external reference point that has been measured or published; none is set by convention.

The XRS scale does not classify protection and presumes no filtration performance. The two dimensions are independent and shall be declared separately.

1 Scope

This document establishes a scale for classifying the breathing comfort of a respiratory protective mask, based on the resistance that the mask opposes to the passage of air. It defines six levels, denoted X1 to X6, each associating a specific resistance interval, a comfort qualification and a breathing endurance expressed as a duration and a wearing context.

This document describes the quantity adopted, establishes its stability with respect to flow rate, sets out the influence of mask geometry on that quantity, justifies each of the six thresholds, provides the application tables corresponding to four use profiles, and reports on the verification of the scale's conformity with standardized physiological limits.

This document is applicable to filtering facepieces and filtering half masks with free ventilation, without powered assistance. It applies to the device alone, in the reference state defined in 3.10, as characterized on a controlled-flow bench.

This document does not apply to self-contained respiratory protective devices, powered ventilation devices, closed-circuit devices or diving apparatus.

NOTE This document does not classify filtration efficiency, does not replace any respiratory protection standard and does not authorize any regulated use. A mask conforming to a given filtration class remains so irrespective of its XRS level; conversely, a favourable XRS level presumes no filtration performance.

2 Normative references and reference documents

This document contains no normative references in the strict sense, in that no provision of another document is made mandatory herein by reference. The documents listed below are cited in the text as sources of measured values, test methods or physiological limits; their full citation is given in the Bibliography.

Document	Role in this reference document
EN 149	Inspiratory and expiratory resistance ceilings by filtration class. Source of the conversion reference points in 7.2 and of the justification of the upper thresholds in 9.3.
ASTM F3502	Two breathability tiers, converted into specific resistance in 12.1.
NIOSH 42 CFR Part 84	Inhalation and exhalation approval ceilings, converted into specific resistance in 12.1.
ISO 16900-12	Method for determining volume-averaged work of breathing and peak pressures. Definition of the quantity used in Clause 11.
ISO 16976-1	Work rates and reference minute ventilations. Linking of use profiles in 13.3.
ISO 16976-4	Physiological limits for work of breathing, peak pressure and elastance. Source of the conformity verification in Clause 13.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
specific resistance
Rs
ratio of the pressure drop measured across a mask to the air flow rate that produces it

Note 1 to entry: Specific resistance is expressed in pascals per litre per second, $\mathrm{Pa/(L{\cdot}s^{-1})}$.

Note 2 to entry: This quantity is the sole input variable of the XRS scale. Its quasi-invariance with respect to flow rate is established in 7.3.

3.2
pressure drop
Δp

difference in pressure between the two faces of a mask through which a given air flow rate passes

Note 1 to entry: Pressure drop is expressed in pascals. It has no meaning unless the flow rate at which it was measured is stated.

3.3
bench flow rate
$\dot{Q}$

constant air flow rate applied to the specimen during the pressure drop test

Note 1 to entry: Bench flow rate is expressed in litres per minute when declared and in litres per second in calculations.

Note 2 to entry: The correspondence between bench flow rate and physiological minute ventilation is established in 7.4.

3.4
XRS level

comfort class assigned to a mask according to the specific resistance interval within which its measured value lies

Note 1 to entry: The levels are denoted X1 to X6, from the most comfortable to the most constraining. They are defined in 9.2.

3.5
inspiratory resistance detection threshold

specific resistance value below which an added resistance is not perceived by the wearer

Note 1 to entry: This threshold constitutes the psychophysical anchor of the scale. It is established by the literature at between 58,8 and 74,5 $\mathrm{Pa/(L{\cdot}s^{-1})}$; see 9.1.

3.6
shape factor
φ

ratio of a reference filtering area to the developed filtering area of the mask under consideration

Note 1 to entry: The shape factor is dimensionless. It expresses the effect of mask geometry on its specific resistance; see 8.2.

3.7
use profile

reference physiological situation, characterized by a bench flow rate and the corresponding minute ventilation, to which the reading of the scale is referred

Note 1 to entry: Four profiles are defined, denoted P1 to P4; see Clause 10.

3.8
work of breathing per tidal volume
WoB/VT

work of breathing of a complete cycle divided by the tidal volume

Note 1 to entry: Work of breathing per tidal volume is expressed in joules per litre, a unit identical to the kilopascal: 1 J/L = 1 kPa.

Note 2 to entry: This quantity constitutes the derived physiological scale of Clause 11.

3.9
face velocity
u

ratio of the air flow rate to the effective filtering area through which it passes

Note 1 to entry: Face velocity is expressed in centimetres per second. It governs the pressure drop of the medium; see 8.1.

3.10
reference state
state of a new, unworn respiratory protective device, removed from its original packaging for the purposes of the test and conditioned in accordance with the test procedure

Note 1 to entry: Specific resistance, and the XRS level derived from it, are determined exclusively in this state. The level characterizes the device as placed on the market, and not as it behaves after any period of use; see 15.1.

Note 2 to entry: A device unpacked long beforehand, worn even briefly, or whose packaging was broken before the test, is no longer in the reference state and cannot serve as the basis for assigning a level.

3.11
breathing endurance
wearing time, expressed by magnitude class, that the breathing resistance of the device alone allows to be envisaged, in the reference state and independently of any other limiting factor

Note 1 to entry: Breathing endurance is one of the three data items associated with each XRS level in Table 7. It states what the resistance permits, not what the product authorizes: the actual wearing time is the minimum of several independent ceilings, foremost among which are the manufacturer's instructions; see 15.1.

4 Symbols and abbreviated terms

Symbol	Designation	Unit
Rs	Specific resistance	$Pa/(L{\cdot}s^{-1})$
Δp	Pressure drop	Pa
$\dot{Q}$	Bench flow rate, inspiratory flow rate	L/min or L/s
$\dot{Q}$peak	Peak inspiratory flow	L/s
$\dot{V}$E	Minute ventilation	L/min
VT	Tidal volume	L
A	Developed filtering area	cm^2
A_ref	Reference filtering area, 236 cm^2	cm^2
u	Face velocity	cm/s
φ	Shape factor	dimensionless
WoB	Work of breathing	J
WoB/VT	Work of breathing per tidal volume	J/L, i.e. kPa
X1 to X6	Levels of the XRS scale	dimensionless
P1 to P4	Use profiles	dimensionless

5 Nature and status of the XRS scale

5.1 Heuristic nature

The XRS scale is a heuristic, that is, a deliberately simplified decision rule, which accepts a loss in exhaustiveness in exchange for a gain in usability. It takes a complex, multifactorial phenomenon, isolates the variable that accounts for most of the observed variance, and produces from it a verdict that can be acted upon immediately.

In engineering, a heuristic is judged on a single criterion: does it produce, within its declared domain of validity, decisions equivalent to those that a complete analysis would have produced, at a fraction of the cost? If so, it is good; if not, it is wrong or its domain is poorly bounded.

A heuristic is not a physical law: it is not expected to hold everywhere and always. It is not a standard: it has no regulatory authority and entails no conformity. Nor is it an opinion: it is quantified, reproducible and verifiable by a third party. It lies exactly between the two, and it is this intermediate position that makes it a design tool.

5.2 Level of proof claimed

A heuristic cannot be proven perfect, and a heuristic that claimed to be so would thereby cease to be a heuristic: if it were exact in every circumstance, it would be a law and would no longer need to be simplified. Claiming perfection would add nothing to the robustness of this reference document and would expose it to immediate refutation by the first counter-example that came along.

The highest level of proof that a heuristic can attain rests on the five properties set out in Table 1, each verifiable individually by a third party. This document establishes them and indicates where.

Table 1 — Properties establishing the level of proof of the XRS scale

Property	Requirement	Clause where it is established
Traceability	Each threshold refers to an external reference point that has been measured or published, and not to an author's choice.	Clauses 7 and 9; verification in Clause 12.
Reproducibility	A third party with the same test bench obtains the same classification, without interpretation.	Clause 7 for the quantity and the method; Clause 11.
Internal consistency	The external reference points, placed back on the scale, are ordered on it without inversion or overlap.	Clause 12 — fifteen independent reference points.
External conformity	The scale, confronted with physiological limits established independently of it, proves compatible with them.	Clause 13 — verification and independent convergence.
Falsifiability	The document states in advance what, if measured, would invalidate the scale.	Clauses 14 and 15.

Position of XALPES LLC

The XRS scale is presented as fully traceable, reproducible, consistent, in conformity with standardized physiological limits and falsifiable — the maximum that can be demonstrated for a tool of this nature. It is not

presented as perfect, and Clause 15 explicitly states the conditions under which it shall have to be corrected. It is this openly accepted refutability that makes the reference document defensible before an expert, and not the reverse.

6 State of the art: absence of a comfort reference document

The question of whether a prior reference document existed was examined before any construction was undertaken. A solid basis exists for measuring breathing resistance, and none for deriving a comfort level from it. It is this gap that justifies the existence of this document.

6.1 What is standardized: measurement, in the service of protection

Several international reference documents set breathing resistance values. All of them, without exception, use those values as physiological safeguards attached to a protection class: resistance is there a ceiling not to be exceeded, never a graded quantity.

Table 2 — Treatment of breathing resistance in existing reference documents

Reference document	Values set	Test flow rate	Declared purpose
EN 149	Inhalation: 60 / 70 / 100 Pa depending on class. At high flow rate: 210 / 240 / 300 Pa. Exhalation: 300 Pa.	30 L/min and 95 L/min; 160 L/min in exhalation	Ceilings attached to the three filtration classes
ASTM F3502	Level 1: ≤ 15 mm H_2O (147 Pa). Level 2: ≤ 5 mm H_2O (49 Pa).	85 L/min	Two breathability tiers, coupled with filtration
NIOSH 42 CFR 84	Inhalation ≤ 35 mm H_2O (343 Pa). Exhalation ≤ 25 mm H_2O (245 Pa).	85 L/min, constant flow	Single approval ceiling
ISO 16900-12	Method for determining volume-averaged work of breathing and peak pressures.	Eight minute ventilation classes, from 10 to 135 L/min	Test method, without comfort threshold
ISO 16976-4	WoB/VT ≤ 0,9 kPa in both inhalation and exhalation and peak pressure ≤ 1,2 kPa up to 105 L/min; 1,6 and 2,0 kPa at 135 L/min. Elastance ≤ 1,0 kPa/L.	The eight minute ventilation classes	Physiological tolerance limits

ASTM F3502 is the text that comes closest to a graduation, with its two breathability levels. But those two levels remain tied to filtration requirements, say nothing about tolerable wearing time, and two tiers do not constitute a scale that can be used in design.

ISO 16976-4 deserves particular mention, as it is the only reference document whose limits are explicitly physiological and not attached to a protection class. It nevertheless grades no further: its limits are built on three criteria, namely insufficient reduction of minute ventilation, insufficient reduction of exercise endurance and avoidance of respiratory distress in eighty to ninety percent of the subjects studied. The standard therefore delimits the breaking point, not the gradation of comfort leading up to it. It does, however, constitute a first-rate verification instrument, to which Clause 13 is devoted.

6.2 What is published: a real but ungraded link

The experimental literature confirms the existence of the link between resistance and perception, and provides quantified reference points of great value. It never goes as far as a rating scale.

— A laboratory study compared three prototypes with respective resistances of 29,4 Pa, 58,8 Pa and 88,2 Pa measured at 85 L/min, worn for one hour on a treadmill by ten subjects. No significant difference was found, on the Borg scale, on thermal comfort, or on perceived inspiratory or expiratory effort. The authors

conclude that lowering resistance below 88,2 Pa no longer brings any measurable benefit to the wearer [8] [9].

— The same authors report the most useful result in the literature consulted: the detection threshold for added inspiratory resistance lies between 58,8 and 74,5 Pa per litre per second. Below it, an additional resistance is not perceived; above it, it becomes perceptible [8].

— A measurement campaign on the best-selling masks gives the order of magnitude of the actual market: 6,1 mm H_2O for an N95, a range of 3,7 to 10,3 mm H_2O for KN95 equivalents, and 2,3 to 9,8 mm H_2O for cloth masks, whose filtration of between 11 % and 33 % disqualifies them in any case. The authors observe that comfort and protection vary there in opposite directions [12].

— A methodological comparison between work of breathing in the ISO sense and resistance in the NIOSH sense establishes a correlation coefficient of 0,7 to 0,9 at the lowest work rate, corresponding to an ordinary walking pace. This result makes it legitimate to build a scale on pressure drop, which is simpler to measure, without losing the physiological content of work of breathing [11].

6.3 What is missing

No standard and no publication proposes a graded comfort scale derived from breathing resistance, or a correspondence between a resistance level and a tolerable wearing time. Standards set ceilings, the literature correlates, but nobody grades.

Three specific gaps can be stated. There is no invariant quantity making it possible to compare masks measured at different flow rates. There is no rating scale linking a resistance level to a use. And mask geometry, which Clause 8 shows largely determines resistance, is taken into account in none of these reference documents.

The XRS scale therefore does not proceed ex nihilo: each of its six thresholds is anchored to a measured or published reference point, Clause 12 verifies that fifteen independent external reference points are correctly ordered on the resulting scale, and Clause 13 confronts it with standardized physiological limits.

7 Physical basis: specific resistance

7.1 Inadequacy of pressure drop alone

A pressure drop expressed in pascals has no meaning in isolation: it depends entirely on the flow rate at which it was measured. A mask at 70 Pa measured at rest and a mask at 70 Pa measured under exertion do not have the same breathability. This is why existing reference documents, each of which sets its own test flow rate, are not directly comparable with one another.

7.2 Quantity adopted

The XRS scale is not built on pressure drop, but on the specific resistance defined in 3.1, obtained by dividing the pressure drop by the flow rate that produced it.

Reference quantity of the XRS scale

$$Rs = \Delta p / \dot{Q}$$

where Δp is the pressure drop measured in pascals and $\dot{Q}$ the test flow rate expressed in litres per second. The result is expressed in pascals per litre per second, $Pa/(L{\cdot}s^{-1})$. This quantity is the sole input variable of the scale.

This choice has a decisive consequence: since Rs does not depend on flow rate, a single six-level scale is sufficient to generate the four use tables of Clause 10. Those tables are not four distinct scales, but four readings of the same scale at four different flow rates.

7.3 Demonstration of quasi-invariance

Physics predicts the stability of Rs: in a fibrous medium traversed at low velocity, the flow is viscous and the pressure drop increases in proportion to velocity; that proportionality makes Rs constant.

This prediction is verified on the normative values themselves, which provide, for three filtration classes, the admissible pressure drop at two distinct flow rates.

Table 3 — Verification of the quasi-invariance of Rs on normative values

Class	Δp at 30 L/min	Corresponding Rs	Δp at 95 L/min	Corresponding Rs
Class 1	60 Pa	120,0 $Pa/(L{\cdot}s^{-1})$	210 Pa	132,6 $Pa/(L{\cdot}s^{-1})$
Class 2	70 Pa	140,0 $Pa/(L{\cdot}s^{-1})$	240 Pa	151,6 $Pa/(L{\cdot}s^{-1})$
Class 3	100 Pa	200,0 $Pa/(L{\cdot}s^{-1})$	300 Pa	189,5 $Pa/(L{\cdot}s^{-1})$

The flow rate is multiplied by 3,17 between the two columns. Specific resistance varies by only +10,5 %, +8,3 % and −5,3 % depending on the class. Invariance is therefore verified to better than ± 11 % over the entire range of use, which is amply sufficient for a scale whose tiers are spaced 30 to 60 units apart.

Declared uncertainty

This reference document adopts an uncertainty band of ± 12 % on Rs to account for the slight non-linearity of the flow at high flow rates. A measurement falling within 12 % of a level boundary is recorded as lying in the overlap band of the two levels; this overlap is reported in the test report, where it honestly expresses the resolution of the scale. The level assigned to the device is then the higher of the two in Rs value, that is, the less favourable in comfort. A device carries only one level, and this rule can never lead to a comfort being announced that is higher

than the one measured. It forms an integral part of the scale: it bounds the scale's resolution without concealing it.

7.4 Correspondence between bench flow rate and minute ventilation

A test bench measures at constant flow, whereas real breathing is cyclic. For a sinusoidal flow, the peak flow rate is π times the minute ventilation. Applied to the four flow rates adopted, this relationship produces the correspondence in Table 4.

Table 4 — Correspondence between bench flow rate and physiological situation

Bench flow rate	Equivalent minute ventilation	Physiological situation	Profile
30 L/min	≈ 10 L/min	Rest, seated position	P1
60 L/min	≈ 19 L/min	Light to moderate activity	P2
95 L/min	≈ 30 L/min	Sustained occupational exertion	P3
140 L/min	≈ 45 L/min	Intense, athletic exertion	P4

The two most widespread normative test flow rates, 30 and 95 L/min, thus correspond exactly to rest and to sustained exertion. The use profiles of this reference document therefore extend, downwards and upwards, an implicit grid already present in existing reference documents.

8 Influence of mask geometry

8.1 Face velocity

The shape of the mask is not a secondary ergonomic parameter: it is a first-order determinant of breathing resistance. What passes through the filtering medium is not a flow rate but a velocity — the face velocity defined in 3.9, obtained by dividing the flow rate by the filtering area presented to the air.

Fundamental relationship

$$u = \dot{Q} / A$$

where u is the face velocity through the medium, $\dot{Q}$ the inspiratory flow rate and A the effective filtering area. Since the pressure drop of a fibrous medium increases in proportion to face velocity, doubling the filtering area halves the resistance, for a strictly identical medium.

Two masks cut from the same medium, with the same filtration efficiency, can therefore exhibit resistances in a ratio of one to three depending on their geometry alone. A flat three-ply mask, whose developed area is constrained by the cut, offers a far smaller area than a duckbill, which exploits its volume to deploy more medium. A so-called boat or fish-type shape lies between the two, while a large-area pleated construction exceeds them all.

The literature provides a direct measurement of this effect: at 85 L/min, a commercial duckbill mask with 236 cm^2 of filtering area imposes a face velocity of 6,0 cm/s, whereas a pleated design of 415 cm^2 — 76 % more area — brings it down to 3,4 cm/s, at comparable filtration performance [14].

8.2 Shape factor

This reference document incorporates this effect in the form of a multiplying coefficient applied to the resistance of the medium alone, which makes it possible to estimate the resistance of a finished mask at the design stage, before any prototyping.

Shape factor

$$\varphi = A\_ref / A$$

with A_ref = 236 cm^2, the area of the reference duckbill measured in the literature, and A the developed area of the mask under consideration. The resistance of the finished mask is then estimated as Rs ≈ φ × Rs_reference: a φ greater than 1 degrades breathability, a φ less than 1 improves it.

Table 5 — Shape factor by geometry

Geometry	Area A	Factor φ	Status of the value
Flat three-ply	≈ 150 cm^2	1,57	XALPES estimate, to be confirmed by measurement
Rigid moulded cup	≈ 180 cm^2	1,31	XALPES estimate, to be confirmed by measurement
Duckbill	236 cm^2	1,00	Published measured value — reference of the scale
Fish type / folded boat	≈ 300 cm^2	0,79	XALPES estimate, to be confirmed by measurement
Large-area pleated	415 cm^2	0,57	Published measured value

NOTE The distinction between measured values and estimates is stated explicitly in Table 5. The three estimates constitute the first task of the measurement programme described in 14.2: they shall be replaced by developed areas recorded on actual parts before the shape factor is used in a contractual specification.

8.3 Face velocity by geometry and by profile

Table 6 gives the face velocity in centimetres per second for each combination of geometry and use profile. It makes it possible to identify problematic configurations: above approximately 10 cm/s, the pressure drop ceases to be linear and breathability degrades faster than the model predicts.

Table 6 — Face velocity u, in cm/s

Geometry	P1 · 30 L/min	P2 · 60 L/min	P3 · 95 L/min	P4 · 140 L/min
Flat three-ply (150 cm²)	3,33	6,67	10,56	15,56
Moulded cup (180 cm²)	2,78	5,56	8,80	12,96
Duckbill (236 cm²)	2,12	4,24	6,71	9,89
Fish type (300 cm²)	1,67	3,33	5,28	7,78
Large-area pleated (415 cm²)	1,20	2,41	3,82	5,62

The reading is unambiguous. A flat three-ply mask crosses the linearity limit as soon as sustained exertion is reached and becomes markedly penalizing at maximal exertion. A duckbill holds up to sustained exertion. Only geometries with a large developed area remain in the favourable domain over the entire range of use. This conclusion directly guides design: to target a high XRS level under exertion, increasing the developed area is a more powerful lever than the choice of medium.

9 Construction of the six-level scale

9.1 Psychophysical anchor

The central anchor point of the scale is the detection threshold defined in 3.5, placed by the literature between 58,8 and 74,5 Pa per litre per second [8]. This threshold has a decisive property: it is already expressed in specific resistance, and therefore directly in the unit of the scale, without any conversion.

It provides the most important boundary of the entire scale, the one that separates what is not perceived from what begins to be. This reference document places that boundary at 60 $Pa/(L{\cdot}s^{-1})$, that is, at the lower bound of the measured band, as a matter of prudence: it is better to announce a resistance as perceptible slightly too early than too late.

A second anchor bounds the scale from below. The same literature establishes that below 88,2 Pa measured at 85 L/min — that is, 62 $Pa/(L{\cdot}s^{-1})$ — any further reduction in resistance no longer brings any measurable subjective or physiological benefit. This result confirms the position of the boundary and signals that a design effort aimed at going below X2 amounts to optimization with no perceived return.

9.2 Reference scale

The complete scale is given in Table 7. It constitutes the core of this reference document; the four tables of Clause 10 derive from it entirely by multiplication by the flow rate of the profile considered.

Table 7 — XRS scale: thresholds, qualifications and breathing endurance

Lvl	Rs $Pa/(L{\cdot}s^{-1})$	Comfort qualification	Breathing endurance
X1	≤ 30	Neutral comfort — resistance not perceptible	**NO LIMIT** — Continuous wear without time limit, including for sensitive groups (children, elderly persons, persons with reduced respiratory capacity) and during sleep.
X2	30 – 60	High comfort — at the limit of perception	**ALL DAY** — Continuous wear over a full day without imposed breaks: office, school, retail, public transport, urban travel.
X3	60 – 100	Ordinary comfort — perceptible, without discomfort	**SEVERAL HOURS** — Wear for several hours interspersed with natural breaks: active standing work, light handling, brisk walking.
X4	100 – 140	Degraded comfort — distinct breathing effort	**1 TO 2 HOURS** — Wear in sequences of one to two hours, followed by a recovery break. Reserved for healthy adults.
X5	140 – 200	Constrained comfort — established breathing discomfort	**UNDER 1 HOUR** — Wear in short sequences, of less than one hour, with mandatory breaks. Trained subject, supervised task.
X6	> 200	Critical comfort — major breathing constraint	**20 TO 30 MINUTES** — Brief and exceptional wear, of the order of twenty to thirty minutes. Verified medical fitness and supervision required. Unsuitable for prolonged wear and for sensitive groups.

NOTE 1 The breathing endurance column is deliberately devoid of any reference to a protection class. This is a construction requirement: comfort and filtration are two independent dimensions, and mixing them in the same column would reproduce the very confusion that this reference document is intended to remove. A mask may be X2 and highly filtering, or X5 and poorly filtering.

NOTE 2 The capitalized wording that opens each row of the breathing endurance column is the normative short form of that data item. It is reproduced word for word, without paraphrase, rounding or conversion, by any document or marking that states an XRS level, and always under the heading "breathing endurance"; the conditions of this use are set in 16.3.4. The wordings for levels X4 to X6 state a ceiling and can only restrict use. Those for levels X1 to X3 state a magnitude: they have an exact meaning only under their heading, which states what the resistance permits and not what the product authorizes, and within the conditions of use stated by the manufacturer; see 15.1.

9.3 Justification of each boundary

Table 8 — Origin of each boundary of the scale

Boundary	Value	Justification
X1 / X2	30	Half of the lower detection bound. Safety margin for groups whose perception threshold is lowered: children, elderly persons, reduced respiratory capacity.
X2 / X3	60	Lower bound of the measured detection threshold (58,8 $Pa/(L{\cdot}s^{-1})$), rounded as a matter of prudence. Boundary between the imperceptible and the perceptible. This is the best-supported boundary of the scale.
X3 / X4	100	Exit from the detection band (74,5 $Pa/(L{\cdot}s^{-1})$) increased by the uncertainty margin, and vicinity of the most demanding published breathability ceiling (103,8 $Pa/(L{\cdot}s^{-1})$). Beyond this point, resistance is no longer merely perceived, it is endured.
X4 / X5	140	Resistance ceiling admitted for the most widespread intermediate filtration class. A mask at this level is at the upper limit of what reference documents tolerate in ordinary use.
X5 / X6	200	Ceiling of the highest filtration class. This boundary receives a second, entirely independent justification: translated into specific resistance, the standardized physiological limits impose Rs ≤ 218 through peak pressure and Rs ≤ 208 through work of breathing, at the highest sustained work rate. See Clause 13.
Beyond X6	242	Most permissive absolute approval ceiling identified. Serves as a safety bound: beyond it, no use can be envisaged.

10 Use tables by profile

The four tables in this clause are the application instruments of the scale. Each corresponds to a use profile characterized by its bench flow rate and its equivalent minute ventilation. They are all generated from the reference scale of Table 7, multiplied by the flow rate of the profile; no value in them is adjusted.

Instructions for use: select the profile corresponding to the intended use; measure the pressure drop at the indicated flow rate; read the level, the qualification and the breathing endurance. If the measurement falls within 12 % of a boundary, record the overlap and retain the less favourable level, in accordance with 7.3.

10.1 Profile P1 — Rest / sedentary

Test flow rate: 30 L/min · **Equivalent minute ventilation:** ≈ 10 L/min

Table 9 — XRS scale applied to profile P1

Lvl	Rs Pa/(L·s^{-1})	Measured Δp (Pa)	WoB/VT (J/L)	Comfort qualification
X1	≤ 30	0 – 15	0,00 – 0,02	Neutral comfort — resistance not perceptible
X2	30 – 60	15 – 30	0,02 – 0,05	High comfort — at the limit of perception
X3	60 – 100	30 – 50	0,05 – 0,08	Ordinary comfort — perceptible, without discomfort
X4	100 – 140	50 – 70	0,08 – 0,11	Degraded comfort — distinct breathing effort
X5	140 – 200	70 – 100	0,11 – 0,16	Constrained comfort — established breathing discomfort
X6	> 200	> 100	> 0,16	Critical comfort — major breathing constraint

10.2 Profile P2 — Moderate activity

Test flow rate: 60 L/min · **Equivalent minute ventilation:** ≈ 19 L/min

Table 10 — XRS scale applied to profile P2

Lvl	Rs Pa/(L·s^{-1})	Measured Δp (Pa)	WoB/VT (J/L)	Comfort qualification
X1	≤ 30	0 – 30	0,00 – 0,05	Neutral comfort — resistance not perceptible
X2	30 – 60	30 – 60	0,05 – 0,09	High comfort — at the limit of perception
X3	60 – 100	60 – 100	0,09 – 0,16	Ordinary comfort — perceptible, without discomfort
X4	100 – 140	100 – 140	0,16 – 0,22	Degraded comfort — distinct breathing effort
X5	140 – 200	140 – 200	0,22 – 0,31	Constrained comfort — established breathing discomfort
X6	> 200	> 200	> 0,31	Critical comfort — major breathing constraint

10.3 Profile P3 — Sustained exertion

Test flow rate: 95 L/min · **Equivalent minute ventilation:** ≈ 30 L/min

Table 11 — XRS scale applied to profile P3

Lvl	Rs Pa/(L·s^{-1})	Measured Δp (Pa)	WoB/VT (J/L)	Comfort qualification
X1	≤ 30	0 – 48	0,00 – 0,07	Neutral comfort — resistance not perceptible
X2	30 – 60	48 – 95	0,07 – 0,15	High comfort — at the limit of perception
X3	60 – 100	95 – 158	0,15 – 0,25	Ordinary comfort — perceptible, without discomfort
X4	100 – 140	158 – 222	0,25 – 0,35	Degraded comfort — distinct breathing effort
X5	140 – 200	222 – 317	0,35 – 0,50	Constrained comfort — established breathing discomfort
X6	> 200	> 317	> 0,50	Critical comfort — major breathing constraint

10.4 Profile P4 — Maximal / athletic exertion

Test flow rate: 140 L/min · **Equivalent minute ventilation:** ≈ 45 L/min

Table 12 — XRS scale applied to profile P4

Lvl	Rs Pa/(L·s^{-1})	Measured Δp (Pa)	WoB/VT (J/L)	Comfort qualification
X1	≤ 30	0 – 70	0,00 – 0,11	Neutral comfort — resistance not perceptible
X2	30 – 60	70 – 140	0,11 – 0,22	High comfort — at the limit of perception
X3	60 – 100	140 – 233	0,22 – 0,37	Ordinary comfort — perceptible, without discomfort
X4	100 – 140	233 – 327	0,37 – 0,51	Degraded comfort — distinct breathing effort
X5	140 – 200	327 – 467	0,51 – 0,73	Constrained comfort — established breathing discomfort
X6	> 200	> 467	> 0,73	Critical comfort — major breathing constraint

NOTE A given mask retains its XRS level whatever the profile, since Rs is invariant. The Δp and WoB/VT columns change from one table to the next because they describe what the wearer actually experiences in the situation considered, which explains why a mask that is comfortable at rest becomes burdensome during brisk walking without having changed in nature.

11 Derived physiological scale: work of breathing

11.1 Justification of the second scale

Pressure drop describes an instantaneous constraint. Work of breathing describes a cumulative energy expenditure, and it is this expenditure, more than peak pressure, that determines fatigue after an hour of wear. It is therefore the quantity closest to what is actually perceived.

Work of breathing per tidal volume, defined in 3.8, is the area of the pressure–volume loop divided by the tidal volume. It is expressed in kilopascals in the standardized method [5], a unit dimensionally identical to the joule per litre. This reference document adopts the joule per litre, which is more meaningful physiologically, and switches to kilopascals in Clause 13 for direct comparison with the standardized limits.

11.2 Derivation of the values

The work of breathing values given in the tables of Clause 10 are not measured: they are calculated from Rs, under three explicit assumptions. The breathing flow is assumed to be sinusoidal, the load purely resistive, and the resistance identical in inhalation and exhalation.

Relationship adopted

$$\mathrm{WoB/VT} = \mathrm{Rs} \times \dot{Q}\mathrm{peak} \times \pi / 2$$

for a complete cycle, with $\dot{Q}$peak the peak inspiratory flow of the profile considered. The result, obtained in pascals, is divided by one thousand to be expressed in joules per litre.

NOTE The assumption of inhalation–exhalation symmetry holds for a mask without a valve and is false for a valved mask, whose expiratory resistance is greatly reduced. For the latter, the calculated value overestimates the actual work and shall be regarded as an upper bound.

11.3 Scope and limitations

This second scale makes visible a phenomenon that pressure drop alone conceals. A mask classified X3 imposes 0,05 to 0,08 J/L at rest, but 0,22 to 0,37 J/L at maximal exertion, that is, a work of breathing multiplied by more than four for a strictly identical resistance. The degradation of comfort with exertion is therefore not linear but quadratic in flow rate: this is the physical explanation for the fact that a mask acceptable at rest quickly becomes burdensome under exertion.

These values remain analytical estimates. They do not replace a measurement on a breathing simulator, which alone makes it possible to account for the actual shape of the cycle, the dead space and the inhalation–exhalation asymmetry. The validation programme of 14.2 provides for their comparison with measurement.

Role of the second scale in the body of proof

It is this second scale that makes the XRS scale verifiable from outside. The standardized physiological limits are expressed in work of breathing per tidal volume and in peak pressure, not in resistance. Without the conversion established in this clause, no confrontation of the XRS scale with those limits would be possible. Clause 13 draws from it one of the most important results of this document.

12 Verification of internal consistency

A scale built on a few anchors might be consistent only with those anchors. The decisive test consists in placing on it all the available reference points — including those that were not used to set any boundary — and verifying that they are correctly ordered.

12.1 Classification of the available reference points

Fifteen independent reference points, drawn from five distinct sources, were converted into specific resistance and classified. No adjustment was applied.

Table 13 — External reference points placed on the XRS scale

Calculated Rs	Level	Reference point
15,9	X1	Most breathable cloth mask measured on the market
20,8	X1	Least resistive laboratory prototype (29,4 Pa at 85 L/min)
34,6	X2	Ceiling of the most demanding published breathability level
41,5	X2	Intermediate laboratory prototype (58,8 Pa at 85 L/min)
42,2	X2	Commercial N95, measured value (6,1 mm H_2O)
58,8	X2 / X3	Lower bound of the psychophysical detection threshold
62,3	X3	"No further benefit beyond" ceiling (88,2 Pa at 85 L/min)
71,3	X3	Least breathable KN95 measured on the market (10,3 mm H_2O)
74,5	X3	Upper bound of the psychophysical detection threshold
103,8	X4	Ceiling of the least demanding published breathability level
120,0	X4	Resistance ceiling of the lowest filtration class
140,0	X4 / X5	Resistance ceiling of the intermediate filtration class
173,1	X5	Exhalation approval ceiling
200,0	X5 / X6	Resistance ceiling of the highest filtration class
242,3	X6	Inhalation approval ceiling — absolute bound

12.2 Result

The fifteen reference points are ordered without any inversion: no commercial mask ends up classified more severely than a regulatory ceiling, and no regulatory ceiling ends up classified more favourably than an optimized laboratory prototype.

The psychophysical detection band, between 58,8 and 74,5, brackets exactly the X2 / X3 boundary set at 60. This band was used only to place that single boundary; the fact that it coincides with it over its full width, without spilling over into X1 or X4, is therefore not a mechanical consequence of the construction.

The masks actually available on the market fall between X1 and X3, whereas the regulatory ceilings occupy X4 to X6. This separation has a strong physical meaning: existing reference documents are safety safeguards, calibrated well above what products actually achieve. It confirms that a comfort scale could not have been derived directly from those ceilings, and justifies a posteriori the approach of this document.

Finally, the three prototypes of the treadmill study fall in X1, X2 and X3, and the absence of any significant subjective difference observed between them is consistent with the fact that all three lie at or below the detection threshold, that is, precisely in the zone where the scale predicts that no difference should be perceived.

NOTE This consistency establishes that the scale is well constructed and compatible with all the available published data. It does not establish that the comfort qualifications and the breathing endurances correspond to what wearers actually perceive: that falls under the experimental validation of Clause 14, which remains to be carried out.

13 Conformity with standardized physiological limits

Clause 12 showed that the scale was consistent with the data used to construct it. This clause carries out a more demanding test: confronting the scale with a set of physiological limits established independently of it, by an international committee, on the basis of an experimental literature that this reference document has not used.

These limits are those of ISO 16976-4 [6]. They concern not comfort but tolerance, and delimit a safety ceiling within which a comfort scale must necessarily lie.

13.1 Translation of the standardized limits into specific resistance

The standardized limits are expressed by minute ventilation class, in the form of a work of breathing per tidal volume and a peak pressure. Their conversion into specific resistance is carried out by means of the relationships established in 7.4 and 11.2.

A first, structural result appears immediately: the standardized limits are constant from 10 to 105 L/min of ventilation, whereas the flow rate is multiplied by more than ten over that range. Translated into specific resistance, they therefore tighten considerably as exertion increases.

Table 14 — Standardized physiological limits converted into specific resistance

Minute ventilation	Peak flow rate	Rs ceiling by peak pressure	Rs ceiling by work of breathing	Ceiling retained
10 L/min	0,52 L/s	2 292	2 189	2 189
20 L/min	1,05 L/s	1 146	1 094	1 094
35 L/min	1,83 L/s	655	625	625
50 L/min	2,62 L/s	458	438	438
65 L/min	3,40 L/s	353	337	337
85 L/min	4,45 L/s	270	257	257
105 L/min	5,50 L/s	218	208	208
135 L/min	7,07 L/s	283	288	283

The most constraining ceiling is therefore reached not at the most intense work rate, but at 105 L/min of ventilation, the last tier before the standard raises its limits. It stands at 208 pascals per litre per second.

13.2 Main result: independent convergence

The XRS scale places the X5 / X6 boundary at 200 pascals per litre per second. This value was set in 9.3 from the resistance ceiling of the highest filtration class, that is, by a purely regulatory route, without any physiological consideration and without knowledge of the standardized limits.

The most constraining physiological ceiling stands at 208 by work of breathing and at 218 by peak pressure. The difference between the boundary of the scale and these two ceilings is four and eight percent respectively, both on the prudent side.

> **Significance of the convergence**

> **200 ≈ 208 ≈ 218**
>
> Two lines of reasoning with nothing in common — one starting from the resistance ceilings associated with filtration classes, the other from physiological tolerance measured on human subjects — designate the same boundary to within ten percent. A coincidence of this nature does not arise by construction: nothing in the approach of 9.3 could have produced it. It constitutes the strongest external validation of this document, and gives the X5 / X6 boundary a physical meaning it did not previously have: X6 is the level at which a mask reaches the ceiling of physiological tolerance in prolonged sustained exertion.

The detailed calculation is as follows. A mask lying exactly at the floor of X6, that is, a specific resistance of 200, loaded at 105 L/min of ventilation, produces an inspiratory work of breathing of 0,864 kPa against a limit of 0,9 kPa, a total work of breathing of 1,727 kPa against a limit of 1,8 kPa, and a peak pressure of 1,100 kPa against a limit of 1,2 kPa. It therefore consumes 96 % of the available physiological margin, without exceeding it.

13.3 Conformity verification of the four profiles

Each profile was first linked to the nearest standardized ventilation class, by applying the relationship of 7.4.

Table 15 — Linking of profiles to standardized ventilation classes

Profile	Bench flow rate	Minute ventilation	Standardized class retained	Assimilation deviation
P1	30 L/min	9,5 L/min	10 L/min	−4,5 %
P2	60 L/min	19,1 L/min	20 L/min	−4,5 %
P3	95 L/min	30,2 L/min	35 L/min	−13,6 %
P4	140 L/min	44,6 L/min	50 L/min	−10,9 %

The rest and moderate activity profiles coincide almost exactly with the first two standardized classes. The exertion profiles fall between two classes and were linked to the upper class, a conservative choice since it assigns to the profile a slightly greater load than the actual one.

Table 16 — Physiological margin at the floor of level X6

Profile	Standardized class	WoB/VT at the floor of X6	Standardized limit	Remaining margin
P1	10 L/min	0,16 kPa	1,8 kPa	91 %
P2	20 L/min	0,33 kPa	1,8 kPa	82 %
P3	35 L/min	0,58 kPa	1,8 kPa	68 %
P4	50 L/min	0,82 kPa	1,8 kPa	54 %

The entire XRS scale, across its six levels and four profiles, lies within the physiologically acceptable domain. No combination exceeds or approaches a standardized limit.

The margin closes steadily with exertion, from 91 % at rest to 54 % at maximal exertion. This decrease is the direct consequence of the structural observation in 13.1: since the standardized limits are constant in work of

breathing whereas specific resistance is constant in resistance, the ratio between the two degrades mechanically with flow rate. This is a property of the scale that must be understood, not a defect: it means that the maximal exertion profile is the one where the scale offers the least margin, and therefore the one to be measured as a priority on an actual product.

13.4 Cumulation of breathing loads

ISO 16976-4 provides a final element that goes beyond verification and enriches the reference document. The standard establishes that the various breathing loads — air flow resistance, static load and elastic load — are additive when each is expressed as a percentage of its own maximum acceptable value, and that a total approaching or exceeding one hundred percent signals discomfort for the wearer.

This additive rule offers a means of eventually reintegrating some of the factors that Clause 15 currently declares outside the model. The XRS level then becomes the contribution of air flow resistance to a total breathing load, to which are added the contributions of the static load — which the standard bounds to an interval of −1 to +1,5 kPa — and of the elastic load, whose ceiling is set at 1,0 kPa/L.

NOTE This prospect is retained as a line of development towards the second edition, without being incorporated at this stage: the static and elastic loads of a flexible filtering mask are small compared with those of a closed-circuit device, and their measurement requires a bench that the Test Laboratory Division does not yet possess.

14 Experimental validation protocol

Internal consistency and external conformity having been established, it remains to verify experimentally that the six levels correspond to six actually distinct perceptions. This is the link that no publication consulted has established and that this reference document proposes to provide.

14.1 Study design

Element	Specification
Type of study	Randomized double-blind crossover trial, each subject wearing all the masks in succession in a randomly drawn order.
Sample size	At least sixty subjects, stratified by sex, age group and physical condition, in order to cover the variability of perception thresholds.
Exclusion criteria	Known respiratory or cardiac pathology, heavy active smoking, inability to perform the exercise of the profile tested.
Specimens tested	At least two masks per level, that is, twelve at minimum, covering the entire range X1 to X6, and of varied geometries so as to test the shape factor as well.
Blinding	Masks presented without marking, in a random order specific to each subject. The operators collecting the scores are unaware of the level of the mask worn.

14.2 Physical measurements

Each mask is characterized on the bench before the human trial. The pressure drop is measured at constant flow at the four profile flow rates, namely 30, 60, 95 and 140 L/min, and the specific resistance is derived from it at each of those flow rates. This repetition makes it possible to verify directly, on the study specimens, the invariance assumption stated in 7.3.

Work of breathing is measured separately on a breathing simulator according to the standardized method [5], in order to compare the analytical values of 11.2 with measurement. The developed filtering area of each mask is recorded, which makes it possible to validate and correct the estimated shape factors of Table 5.

14.3 Subjective measurements

Two validated instruments are adopted, measuring two distinct dimensions. The Borg category-ratio scale, graduated from zero to ten, measures the intensity of breathing discomfort; its author explicitly recommended it for the assessment of dyspnoea [16][17]. A visual analogue scale from zero to one hundred measures in parallel the overall perceived comfort, a broader dimension that incorporates heat, humidity and pressure on the face.

Readings are taken at the initial instant and then every twenty minutes during sixty minutes of wear under exertion conditions corresponding to the profile tested. This time course is essential: it alone makes it possible to substantiate the wearing times stated in Table 7.

Accompanying physiological measurements are collected continuously — heart rate, respiratory rate, oxygen saturation and temperature under the mask — in order to distinguish discomfort of respiratory origin from discomfort of thermal origin.

14.4 Analysis and success criteria

Table 17 — Success criteria for the validation

Analysis	Method	Success criterion
Resistance / discomfort relationship	Spearman correlation between Rs and the Borg score at sixty minutes	$\rho \geq 0{,}70$
Separation of levels	Paired comparisons between adjacent levels, correction for multiple testing	At least four of the five boundaries significantly separate two populations of scores
Position of the X2 / X3 boundary	ROC curve of reported detection as a function of Rs	The optimal threshold falls within the band 58,8 – 74,5
Monotonicity of the scale	Verification of the order of median scores from X1 to X6	No inversion between two adjacent levels
Stated wearing times	Survival analysis on withdrawal or on exceeding a Borg score of 5	The observed median durations bracket the durations stated in Table 7
Shape factor	Regression of Rs on the inverse of the developed area	Slope compatible with the predicted proportionality, $R^2 \geq 0{,}8$

These criteria are set before the study and will not be revised afterwards. This is what gives the approach its meaning: they make the scale refutable by its own data.

15 Declared limitations and conditions of refutation

15.1 Factors not taken into account

Breathing resistance does not account for the whole of a mask's comfort. Five important factors are deliberately excluded from the model, and this exclusion must be known to anyone using the scale.

— Thermal and hygrometric comfort. The build-up of heat and humidity under the mask is a major cause of discomfort, independent of resistance. An X1 mask may be unbearable because of its heat.

— Mechanical pressure and fit. The bearing points on the bridge of the nose and the cheekbones, the tension of the straps and skin irritation bear no relation to pressure drop.

— Dead space and carbon dioxide rebreathing. This factor depends on the internal volume of the mask, and therefore paradoxically on the very geometry that improves breathability. A mask with a large developed area may improve its XRS level while worsening its rebreathing.

— Clogging in use. The resistance measured is that of a new mask, in the reference state defined in 3.10. It increases with dust loading and humidification, so that the effective resistance in service may fall under a less favourable level than the level assigned. This drift depends on the working atmosphere, that is, on conditions external to the device: it is not a characteristic of the product, and the XRS level describes exclusively the reference state. A device carries only one level; no pair of levels, no interval and no "in-service" or "after clogging" level may be assigned to it.

— Hygiene and surface contamination. The outer surface of a mask becomes loaded by deposition and handling, and exhaled moisture promotes microbial growth in the medium. These phenomena bound the period of use without any relation to breathing resistance.

These five factors justify that the XRS level is always presented as a breathing comfort classification, and never as an overall comfort classification.

It follows that the actual wearing time of a device is the minimum of several independent ceilings — breathing endurance, the only one established by this document, clogging, humidity, hygiene, maintenance of fit — and, foremost, the manufacturer's instructions, which prevail over everything else. The NR marking of EN 149, which limits the use of a filtering half mask to a single work shift, is the most common example. A breathing endurance of "no limit" means that the resistance imposes no limit; it never authorizes use beyond the conditions set by the manufacturer. The XRS level is understood, in all circumstances, for a new mask and within the manufacturer's stated conditions of use.

Two of these factors now have a route to reintegration. The additive rule for breathing loads set out in 13.4 makes it possible to treat static load and elastic load as contributions expressed as a percentage of their own ceiling, cumulative with the contribution of the XRS level. This extension is on the programme for the second edition. Thermal comfort, clogging and hygiene remain outside the model and will remain so: they belong to a different physics, and integrating them would mean weighting quantities of different natures against one another, that is, substituting a composite judgement for a single measurement.

15.2 Limitations of the physical model

The invariance of specific resistance is verified only to ± 12 %, and this approximation deteriorates above a face velocity of approximately 10 cm/s, a regime that Table 6 shows is reached by flat geometries as soon as sustained exertion is reached. For those configurations, direct measurement at the flow rate of use shall take precedence over extrapolation.

The shape factor assumes that the entire filtering area is traversed uniformly, which is never strictly the case: fold zones and edges are less loaded. The factor is therefore a theoretical optimum, and the effective area is smaller than the developed area.

The work of breathing values are analytical and assume inhalation–exhalation symmetry, an assumption that is false for any valved mask.

15.3 Conditions of refutation

In accordance with the principle of falsifiability stated in 5.2, the observations in Table 18 would constitute a refutation, total or partial, and would trigger a revision.

Table 18 — Conditions of refutation of the XRS scale

Observation	Consequence
Correlation between Rs and the Borg score below 0,50	Refutation of the very principle of the scale: resistance would not be sufficient to predict comfort. Complete overhaul.
Experimental detection threshold outside the band 58,8 – 74,5	Shift of the X2 / X3 boundary and repositioning of the entire scale.
Inversion of two adjacent levels in the median scores	Merging of the two levels concerned or redefinition of their boundary.
Variation of Rs greater than 25 % between 30 and 140 L/min on the specimens tested	Abandonment of the single scale in favour of four independent scales by profile.
Observed wearing times shorter than the stated times by more than half	Revision of the breathing endurance column, without calling the thresholds into question.
Shape factor regression with R^2 below 0,5	Removal of the shape factor from the predictive model, retained for information only.
Work of breathing measured on the simulator exceeding the analytical value of 11.2 by more than 30 %	Replacement of the analytical relationship by a law fitted to measurement, and re-examination of the conformity verification of Clause 13.
Exceedance of a standardized physiological limit by a mask classified X5 or below	Lowering of all the upper boundaries. This would be the most serious refutation, as it would mean that the scale declares comfortable a mask that is physiologically unacceptable.

16 Governance, revision, trademarks and distribution

16.1 Status of this edition

This document constitutes the first edition of the reference document, known as the founding edition, published openly. It is complete with regard to the construction of the scale, its physical basis, its documentary verification and its physiological conformity verification. It can be used in design and in technical specification.

Its open publication stems from a deliberate choice. A classification scale is worth only as much as its adoption: a reference document that no one can read classifies nothing. A scale that states its own conditions of refutation, as Clause 15 does, by construction calls for external examination; to withhold it from such examination would be contradictory. XALPES LLC therefore publishes this work so that it may be used, cited and challenged.

The experimental validation on a human panel described in Clause 14 had not been carried out at the date of publication. Any declaration of an XRS level established on the basis of this edition shall state this status.

16.2 Revision

A second edition will be prepared on completion of the validation programme of Clause 14. It will incorporate the developed areas measured on actual parts, the work of breathing values measured on the simulator in place of the analytical values, the extension to the cumulation of breathing loads set out in 13.4, and the threshold corrections that the data will require.

Any modification of a threshold, a qualification or a breathing endurance gives rise to a new numbered edition, accompanied by the justification for the modification and the data that motivated it. Earlier editions are preserved and remain accessible on the scalexrs.com website, marked as superseded, so that a third party can reconstruct the history of decisions. This archiving requirement forms part of the traceability claimed in 5.2.

16.3 Trademarks and conditions of use of the designation

16.3.1 Trademarks claimed

XALPES™ and XRS™ are trademarks of XALPES LLC. The level designations X1 to X6, used in relation to the classification defined by this document, form part of the same distinctive sign and are covered by the same claim.

The claim extends to the figurative elements that accompany the designation: the XRS logotype reproduced below, composed from the letters of the XALPES logotype, its signature line "Classification du confort respiratoire" and its English equivalent "Breathing comfort classification", the cut-corner badge bearing the level designation, the isolated X glyph and the design of the numerals 1 to 6. These elements are used in graphite ink, distinct from the red of the XALPES trademark, so that the sign reads as a classification instrument affixed to a third party's product, and not as the emblem of its publisher.

These trademarks are claimed on the basis of use in commerce. The publication of this document, on the date shown on the cover, constitutes documented evidence of first use, both of the designation and of the figurative elements that accompany it.

NOTE The ® symbol is not affixed to any of these trademarks and shall not be affixed by any third party. It is reserved for trademarks actually registered with the competent office; its use on an unregistered trademark is unlawful in several jurisdictions, including the United States of America, and may impede the subsequent exercise of the rights attached to the sign.

16.3.2 Correct form of use

A trademark is an adjective, not a noun. The designation XRS is used exclusively as a qualifier accompanying a generic noun, never alone, never in the plural, never in the possessive and never as a verb. This requirement is not a matter of style: repeated use of a trademark as a noun leads to its genericide, that is, to the loss of the distinctive character on which protection is founded.

Table 19 — Forms of use of the designation

Correct form	Prohibited form
the XRS scale	the XRS
an XRS level of X2	an XRS of X2
the XRS reference document	the XRSs
the measured specific resistance is 45 Pa/(L·s^{-1})	the mask's XRS is 45
mask classified at XRS level X2	XRS'd mask, XRS 45 mask
in conformity with the XRS 001:2026 reference document	XRS compliant

16.3.3 Citation

Citation of this reference document for purposes of study, teaching, research or comparison is free, subject to full attribution stating the reference number, the edition and the publisher, in the form: XRS 001:2026, XRS scale, first edition, XALPES LLC.

The ™ symbol is affixed at the first or the most prominent occurrence of each trademark in a document. Its repetition at every occurrence is neither required nor desirable.

16.3.4 Commercial use

The use of the designation XRS or of a level designation X1 to X6 to designate, qualify, label, promote or market a product is subject to written authorization from XALPES LLC, which alone is empowered to attest that a measurement has been carried out in accordance with this reference document.

Any authorized third party shall display the following statement on its materials: "XRS™ is a trademark of XALPES LLC, used under licence."

Any marking that states an XRS level shall reproduce, under the heading "breathing endurance", the normative short wording of Table 7 corresponding to the level assigned, and shall bear in plain text the statement "New respirator · Within the manufacturer's stated conditions of use". The level appears there alone, never juxtaposed with a filtration class within the same graphic block. The detailed conditions of measurement, declaration and marking are set out in the technical annex to the licence, referenced XRS 002.

NOTE Where the designation is intended to attest that a third party's product satisfies this reference document, the sign falls under the regime of certification marks. That regime carries its own obligations, in particular effective control of use, non-discriminatory application of the reference document to any applicant that satisfies it, and, in several jurisdictions including the United States of America, a prohibition on the owner itself producing or marketing the goods bearing the mark. The choice of the applicable regime is examined in 16.4.

16.4 Protection to be consolidated

This edition claims the trademarks on the basis of use, without registration. Three actions are identified as prerequisites to any external distribution of the reference document or to any grant of licence.

— Prior-art search and filing of the XRS trademark with the competent office, in its word form and in its figurative form as defined in 16.3.1, in the classes corresponding to testing and technical validation services on the one hand, and to the products concerned on the other.

— Decision between an ordinary trademark and a certification mark, in view of the product development activity carried out by XALPES LLC. The two regimes are, for the same sign and the same scope of goods, difficult to combine.

— Verification that no element of the arrangement — measurement bench, test method, design derived from the shape factor study — is eligible for patent protection, since any public disclosure destroys novelty in most jurisdictions.

NOTE The considerations in this subclause are informative in scope and do not constitute legal advice. They are to be submitted to an intellectual property attorney before any decision on filing or distribution.

16.5 Distribution and versions

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16.6 Contact

Any request for authorization, any feedback, any challenge to a threshold and any proposal of new data are to be addressed to XALPES LLC, Test Laboratory Division, at contact@xalpes.com.

Bibliography

Normative reference documents

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[2] Masque de protection FFP — synthèse des exigences de la norme européenne. → link *Cross-check of the values in [1].*

[3] ASTM F3502-21 — Standard Specification for Barrier Face Coverings. Breathability levels. → link *Level 1 ≤ 15 mm H_2O; level 2 ≤ 5 mm H_2O at 85 L/min.*

[4] Overview of the ASTM F3502-21 Barrier Face Covering Standard — NIOSH Science Blog, CDC. → link *Institutional cross-check source for [3].*

[5] ISO 16900-12:2016 — Respiratory protective devices: methods of test and test equipment, Part 12: Determination of volume-averaged work of breathing and peak respiratory pressures. → link *Method for measuring work of breathing, unit and test parameters.*

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