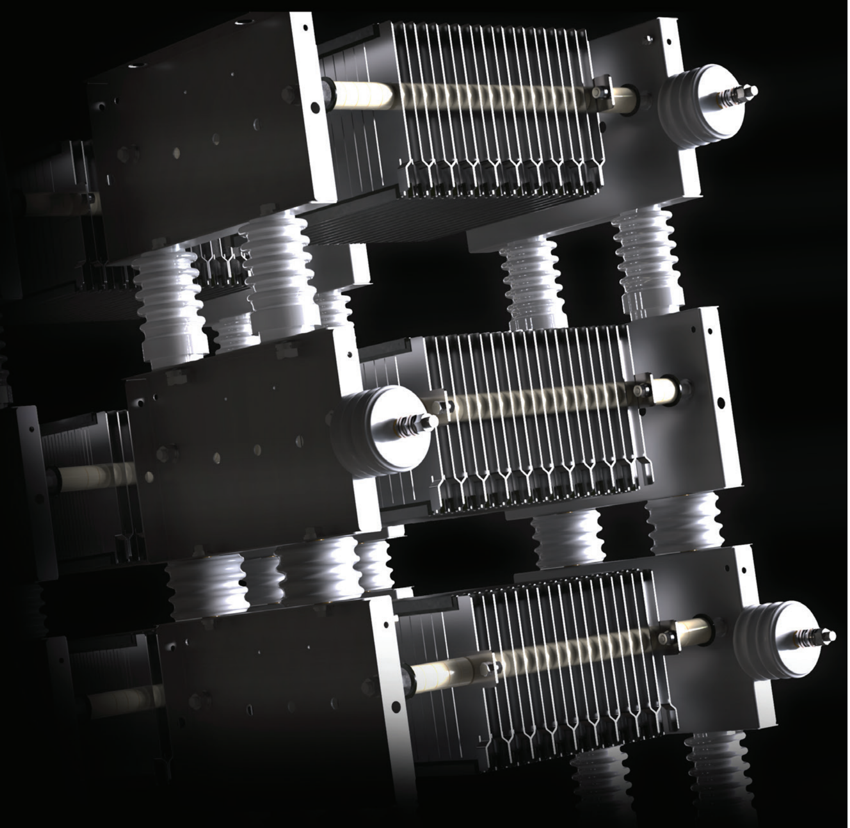
DANOTHERM

Neutral Earthing Resistors



Controlled Fault current

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Quick Reference

The table below provides a rapid overview of typical configurations based on system voltage, earth-fault current and fault duration. Use it as a starting point — final specification is always based on the specific system study.

System voltage (kV)	Earth-Fault Current (A)	Duration (s)	I^2t (kA^2s))	Configuration	Material
6 - 12	< 50 (HRG)	Continuous	-	1NER	AISI 304 / other on request
6 - 12	50 - 200	10	25 - 400	1NER	AISI 304/ other on request
12 - 22	200 - 500	10	400 - 2.500	2NER	AISI 304/ other on request
22 - 36	500 - 2000	10 - 60	2.500 - 240.000	3NER	AISI 304/ other on request
Up to 36	All levels	Up to 60	Project-specific	Custom	AISI 304/ other on request

Selection Logic

- HRG (< 50 A): Use 1NER with continuous current rating — service continuity is prioritised over fast clearing
- LRG 50–200 A: 1NER is typically sufficient for standard applications up to 12 kV
- LRG 200–600 A: 2NER recommended to distribute thermal duty (I^2t)
- LRG > 600 A or high I^2t: 3NER or custom solution — contact Danotherm
- Shorter fault duration = lower I^2t = smaller/lighter unit. Reserve 1NER for < 400 kA^2s

Standards: IEEE 32 · IEC 60071-1 · IEC 60529
Tolerance: ±10% (tighter on request)

Final configurations are application specific.

Neutral Earthing Resistors

Neutral earthing resistors (NER) limit earth-fault current in 6–36 kV or higher systems to control thermal stress, reduce arc-flash risk and ensure reliable protection operation.

NER sizing is defined by system voltage, required earth-fault current and protection clearing time.

System Behaviour

Earth-fault current level defines system behaviour and protection performance:

- Low resistance → high fault current → strong relay signal → high thermal and mechanical stress
- High resistance → low fault current → reduced stress → requires sensitive protection
- Stable resistance ensures predictable fault current and correct relay pickup
- Thermal design is based on adiabatic heating (I^2t)
- Resistance value directly determines relay sensitivity and selectivity

Application Context

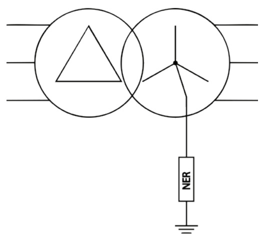
NERs are applied in:

- Transformer neutral grounding
- Generator neutral grounding
- Grounding transformer systems (zig-zag or wye-delta)

Design Purpose

Used to:

- Limit thermal and mechanical stress during earth faults
- Control arc-flash energy and voltage dip
- Enable selective and reliable earth-fault protection



NERs must not be used in systems with single-phase loads (e.g. lighting circuits) unless supplied through an isolation transformer, as temporary overvoltage can reach line-to-line level.

Design & Construction

Design drivers

NER design is defined by four key parameters:

- System voltage → insulation level, clearances and geometry
- Fault current → electrodynamic forces and mechanical design
- Fault duration → thermal capacity and resistor mass
- Installation environment → enclosure design and material selection

Resistor Element & Thermal Design

- Resistor elements in AISI 304 / 310 / 430 or ceramic wirewound, selected according to required I^2t duty and temperature rise
- Thermal design is based on adiabatic heating
- Fault energy (I^2t) defines element mass and enclosure size
- Thermal capacity determines allowable fault duration and repeated-fault capability
- Low resistance drift over temperature ensures stable fault current and reliable relay pickup

Mechanical Design

- Structure designed to withstand electrodynamic forces from the specified earth-fault current
- Design accommodates thermal expansion without deformation
- Clearances and creepage distances defined by system voltage / customer specification

Enclosure & Cooling

- Enclosure design balances cooling performance and IP protection
- Higher IP reduces natural convection and increases thermal requirements
- Standard enclosures in galvanised steel; stainless steel available for corrosive environments
- Enclosures can be painted on request

Connections

- Cable or bushing terminations selected according to insulation level and installation layout
- Connection design must ensure required clearances and reliable current path under fault conditions

Auxillary Options

- Current transformers for fault monitoring and protection integration
- Disconnect links or switching devices for maintenance and isolation
- Special designs available for high altitude or increased insulation requirements
- Remote monitoring options (combined active and passive in one device):
  - Active → direct resistance measurement, including de-energized systems
  - Passive → estimation based on system current/voltage during operation
- Enables supervision of critical installations such as backup power and emergency systems

Electrical Ratings and Selection

Engineering Trade-offs

- Fault current → detection vs stress
- Duration → thermal sizing
- Voltage → insulation constraints
- System integration → placement/role

HRG vs LRG

HRG	LRG
<50 A	50 - 2000 A
Low damage	Reliable detection
Service continuity	Fast clearing
Needs monitoring	Standard protection

System Integration

NER must be coordinated with system configuration:

- Transformer neutral
  → defines earth-fault current level
  → must match insulation level

- Generator neutral
  → limits stator earth-fault current

- Grounding transformer
  → creates artificial neutral
  → must be rated for fault current

Key Requirement

Stable resistance during the fault is essential to ensure predictable fault current and reliable protection operation.

Fault Current Selection

The selected earth-fault current defines system behaviour:

- Higher current
  → strong relay signal
  → fast detection
  → higher thermal (I^2t) and mechanical stress

- Lower current
  → reduced stress
  → requires sensitive protection
  → may limit detection on long feeders

Electrical Ranges

Design ranges:

System voltage: up to 36 kV / or higher
Earth-fault current: 5–2000 A / or higher
Short-time duty: 1–60 s
Resistance tolerance: ±10% (tighter on request)

System Voltage

System voltage defines:

- Insulation level
- Clearance and creepage distances
- Enclosure dimensions and connection layout

Fault Duration

Fault duration defines:

- Thermal capacity (I^2t)
- Resistor size and mass
- Continuous current may be required in HRG systems

Configuration Selection

When 1NER, 2NER or 3NER?

Configuration is determined by fault current, I^2t duty and thermal capacity requirement. The table below is indicative — final configuration is always based on the system study and thermal calculation.

Parameter	1NER	2NER	3NER
Fault current (typical)	5 - 200 A	200 - 600 A	600 - 2.000 A
I^2t capacity	Up to ~ 400 A^2s	Up to ~ 2.500 A^2s	Up to ~240.000 A^2s
Columns	1	2	3
Width (indicative)	700 - 1.100 mm	1.400 - 1.900 mm	2.850 mm
Typical system	HRG, generator neutral, low current	LRG distribution, medium transformers	LRG high I^2t, large transformers, industry

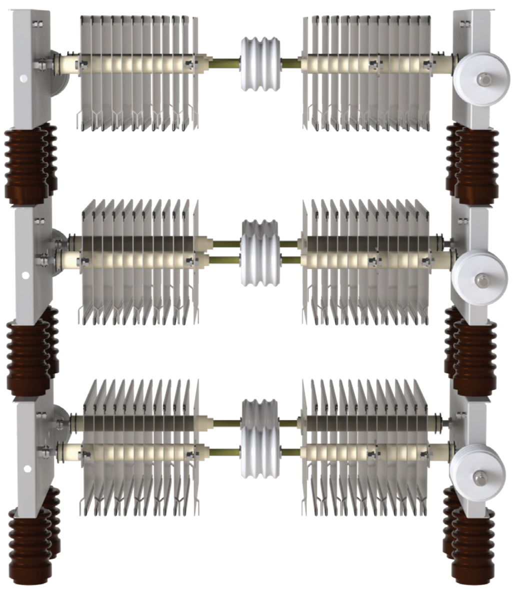
Design output

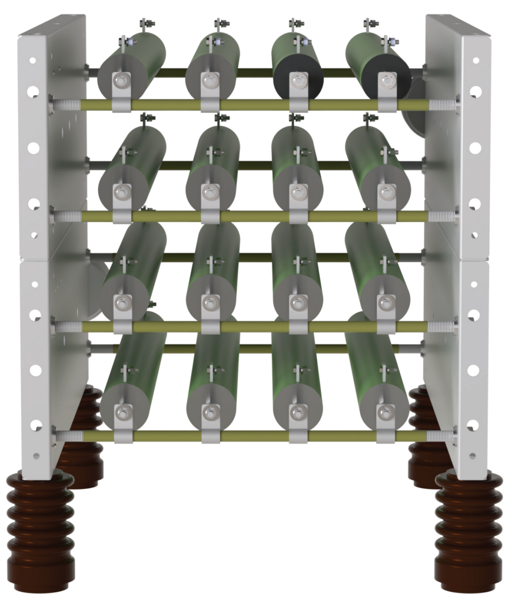
Based on system parameters, the NER is defined by:

- Resistance value
- Thermal capacity (I^2t)
- Mechanical configuration (1NER / 2NER / 3NER)
- Enclosure and cooling design

HRG systems → typically 1NER configuration with continuous current rating
LRG systems → 2NER or 3NER depending on current level and thermal duty

Low resistance, high current = Steel racks
High resistance, low current = Wire wound





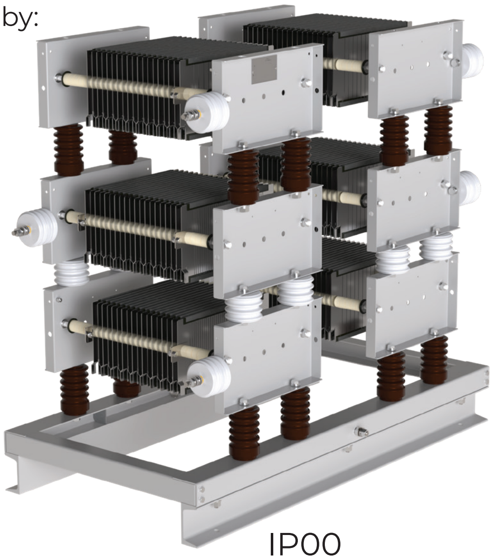
Design Definition

Based on the defined system parameters, the NER design is specified by:

Materials

- Resistor elements: AISI 304 / 310 / 430 or FeCrAl alloys
- Structure: galvanised or stainless steel
- Insulators: high-temperature ceramic
- Enclosure painting on request

Material selection is based on thermal duty, corrosion exposure and required lifetime.



IP00

Certifications & sector specifications

ISO 9001 (quality management) and **ISO 14001** (environmental management) certified. NERs are designed and tested in accordance with **IEEE 32, IEC 60071-1** and **IEC 60529**. Additional sector specifications supported on project request:

- **EDF HN 64-S-50** — French utility specification for MV neutral grounding resistors
- **UNE 21110** — Post insulators for MV indoor/outdoor use
- **UNE-EN 60137** — Bushings for AC voltages above 1000 V

Configuration

NER solutions are available as:

- Single or multi-column resistor units
- Indoor or outdoor enclosures (IP00–IP55+)
- Integrated assemblies with CTs, monitoring and switching

Each unit is configured to match system requirements.

IP23

Technical Data and Configurations

- **EDF HN 64-S-50** — French utility specification for MV neutral grounding resistors
- **UNE 21110** — Post insulators for MV indoor/outdoor use
- **UNE-EN 60137** — Bushings for AC voltages above 1000 V

Technical data

System voltage:
6 – 36 kV

Fault current:
5-2.000 A

Short-time rating:
1 – 60 seconds

Continuous current
If required

Cooling:
Self cooled (Natural convection)
Forced air-cooling available on request

Resistance tolerance:
±10% standard, tighter on request

Materials:
AISI 304 / 310 / 430

Enclosure:
Galvanized steel, optional stainless or coated

Ingress protection:
IP00 - IP23, up to IP54 on request

Connections:
Cable or bushing

Standards:
IEEE 32, IEC 60071-1, IEC 60529, EDF HN 64-S-50, UNE 21110, UNE-EN 60137

Altitude derating:
According to IEEE 32

Special requirements on request

Configuration types - General info

NER units are supplied as:

- 1NER – single column
  → compact design
  → low fault current applications
- 2NER – two column
  → medium thermal capacity
  → medium fault current range
- 3NER – three column
  → high thermal capacity
  → higher fault current applications

Application Correlation

- HRG systems
  → 1NER configurations
- LRG systems
  → 2NER or 3NER configurations

Configuration is determined by current level, time rating and thermal duty.

Connection and Installation

- Cable or bushing termination depending on insulation level and layout
- Galvanised steel enclosure as standard
- Stainless steel available for corrosive environments
- IP rating selected based on installation conditions

Optional Features

- Current transformers (CT)
- Monitoring relays
- Disconnect switches
- Special enclosure design

Indicative Dimensions

Indicative values only. Final dimensions depend on voltage, current, time rating and enclosure design.

Configuration	High (mm))	Width (mm)	Length (mm)
1NER	1.190 - 2.380	700 - 1.100	1.350 - 16.00
2NER	1.190 - 2.380	1.400 - 1.900	1.350 - 1.600
3NER	1.190 - 2.380	2.850	1.350 - 1.600

Floors	2	3	4	5	6	7	8	9
High	1.190	1.360	1.530	1.700	1.870	2.040	2.210	2.380

1NER

2NER

3NER

Ratings

Voltage	Resistance	Current	Time
12 kV	75 Ω	50 A	10s
12 kV	14 Ω	500 A	10s
11 kV	27,5 Ω	200 A	10s
22 kV	63,5 Ω	200 A	10s

Typical values; others available on request

Design Output

Based on system parameters, the NER is defined by:

- Resistance value
- Thermal capacity (I^2t)
- Mechanical configuration (1NER / 2NER / 3NER)
- Enclosure and cooling design

- Continuous current may be required in HRG systems to handle network charging current

- Final design is based on system study and protection requirements

Testing, Certification and Delivery

Delivery and service

- Standard lead time: 6-10 weeks from order confirmation
- Express delivery available on request
- Spare parts available

Standard tests

- Measurement of insulation resistance between enclosure and resistor
- Dielectric test 50Hz / 1 minute between active part and housing (voltage levels up to 120 kV conform directive IEC 60298:1990)
- Measurement of inductance value
- Measurement of DC resistance
- Measurement of metal surface thickness (galvanized DX51D+Z275-M-A-E or painted)
- Dimensional check according relevant drawings

Type tests (upon request)

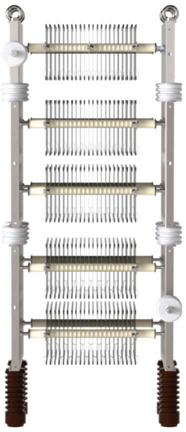
- Temperature rise test
- BIL test
- impulse voltage test (1.2 / 50 μs)
- AC resistance test
- Ingress Protection test
- Seismic test

Certifications and Standards

- ISO 14001 and ISO 9001
- Design and testing in accordance with IEEE 32
- IEC 60071-1 — insulation and transformer coordination
- IEC 60529 — IP classification
- EDF HN 64-S-50: Technical specification for the supply of single-phase metallic resistors for neutral grounding in medium-voltage networks
- UNE 21110: Post insulators for indoor or outdoor use, made of ceramic or glass, for installations with a rated voltage above 1000 V
- UNE-EN 60137: Bushings for alternating voltages above 1000 V

IP00

- 1NER
- 540 Ω
- 20 A - 5 s
- 17,5 kV



IP23

- 2NER
- 25 Ω
- 400 A - 10 s
- 17,5 kV

IP54

- 1NER
- 39,8 Ω
- 100 A - 10 s
- 6,6 kV

Engineering selection workflow – practical example

This example shows how system data defines resistance, thermal duty and final NER configuration.

System data

Parameter	Value	Engineering Notes
System voltage (Ur)	12 kV	Phase voltage: $V_{\text{phase}} = {}^{12}\!/\!_{\sqrt{3}} = 6{,}93\ \text{kV}$
Grounding philosophy	LRG	Distribution feeders
Desired earth-fault current	200 A	Relay vs thermal balance
Protection clearing time	10 s	Worst-case backup clearing
Installation	Outdoor, IP23	Natural convection acceptable
Environment	Coastal, moderate corrosion	AISI 304 suitable
Neutral insulation level	Standard transformer neutral	No special insulation required

1. Calculate Required Resistance

$$R = \frac{V_{\text{phase}}}{I_{\text{fault}}} \quad = \quad R = \frac{6.930}{200} = 34{,}7\ \Omega$$

Acceptable working range: 34–36 Ω, based on ±10 % tolerance (“Resistance tolerance typically +10%”).

2. Calculate Thermal Duty (I^2t)

$$I^2t = I^2 \cdot t = 200^2 \cdot 10 = 400.000\ \text{A}^2\text{s}$$

Engineering implications:

- Medium thermal stress
- AISI 304 or 310 resistor elements suitable
- Single-event duty, not repeated cycling
- Natural convection sufficient at IP23

3. Mechanical Withstand

- Electrodynamic forces scale with I^2
- 200 A → moderate electrodynamic forces
- No additional reinforcement required

4. Enclosure & Cooling Selection

IP23 provides:

- Natural convection cooling
- Minimal thermal derating
- No need for forced ventilation

IP23 is optimal for this application.

5. Material Selection

Based on:

- I^2t = 400 kA^2s
- Outdoor installation
- Moderate corrosion environment

Recommended configuration:

- Resistor elements: AISI 304
- Enclosure: Galvanised steel (stainless optional)
- Connections: Cable terminations

6. Select Configuration

For 200 A, 10 s duty:

- Single-stack 1NER configuration is sufficient
- No need for multi-stack thermal distribution
- Height: 1.3–1.6 m (within range “1190–2380 mm”)

System data

Parameter	Value
System voltage	12 kV
Resistance	35 Ω (±10 %)
Earth-fault current	200 A
Duty	10 s
I^2t	400 kA^2s
Enclosure	IP23, galvanised steel
Cooling	Natural convection
Resistor elements	AISI 304
Configuration	1NER
Connections	Cable lugs
Installation	Outdoor

Zig-Zag Grounding Transformer + NER – Practical Example

Zero-sequence based calculation

System data

Parameter	Value	Engineering Notes
System voltage (Ur)	22 kV	Phase voltage: $V_{\text{phase}} = {}^{22}\!/\!_{\sqrt{3}} = 12{,}7\ \text{kV}$
Grounding philosophy	LRG (artificial neutral)	Artificial neutral
Desired earth-fault current	150 A	Detection vs stress
Protection clearing time	10 s	Backup clearing
Installation	Outdoor, IP23	Natural convection
Environment	Industrial, moderate pollution	Standard conditions
Grounding transformer	Zig-Zag	Neutral established
Transformer impedance	$R_0 = 3\ \Omega,\ X_0 = 35\ \Omega$	Zero-sequence values

1. Required impedance

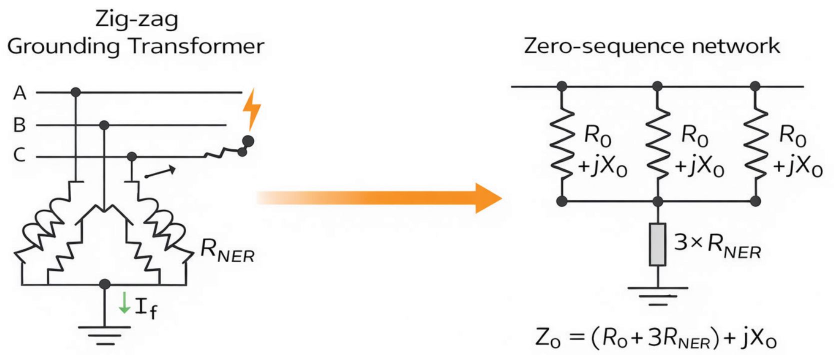
$$\left|Z_0\right| = \frac{12.700}{150} = 84{,}7\ \Omega$$

2. Zero sequence model

In grounding transformer systems:

Transformer impedance: $R_0 + jX_0$
NER appears as: 3 × R

$$Z_0 = (R_0 + 3R_{\text{NER}}) + jX_0$$



NER is represented as 3 × R in the zero-sequence network

- Total impedance defines earth-fault current

3. Calculate required resistance

$$R_{\text{NER}} = \frac{\sqrt{|Z_0|^2 - X_0^2} - R_0}{3}$$

$$R_{\text{NER}} \approx 24{,}5\ \Omega$$

4. Calculate thermal duty (I^2t)

$$I^2t = 150^2 \cdot 10 = 225.000\ \text{A}^2\text{s}$$

5. Engineering implications

- Fault current defined by total impedance
- NER depends on transformer impedance
- Tolerance (±10%) affects relay settings
- Low current → higher sensitivity
- High current → higher stress

6. Select configuration

For 150 A, 10 s duty:

- Moderate thermal duty
- Natural convection sufficient (IP23)
- Single-stack (1NER) configuration

Result

Parameter	Value
System voltage (Ur)	22 kV
Resistance	~25 Ω (±10%)
Earth-fault current	150 A
Duty	10 s
I^2t	225 kA^2s
Enclosure	IP23, galvanised steel
Cooling	Natural convection
Resistor elements	AISI 304
Configuration	1NER
Installation	Outdoor

Applications and Sector Experience

Danotherm delivers NER solutions across a wide range of sectors and applications — from standard utility substations to specialised offshore and renewable energy installations.

Sectors and Applications

Sector	Typical application	Relevant Features
Utility / Transmission	Substation, 22–36 kV neutral grounding	LRG, 2NER/3NER, IP23
Renewable Energy	Wind turbine collector system, generator neutral, zig-zag transformer	Remote monitoring, corrosion protection, offshore-rated
Industry / Process	Factory supply, HRG systems with service continuity	HRG, 1NER, continuous current, monitoring relay
Offshore / Marine	Platform, FPSO, offshore wind substation	Stainless steel enclosure, IP55+, salt-water resistant
Data centre / Critical infrastructure	Generator neutral, backup-power earthing	Active + passive remote monitoring, high reliability

Application examples

- Offshore wind farm, North Sea — 33 kV collector transformer, 2NER, IP55, stainless steel enclosure
- Nordic utility transmission substation — 22 kV neutral grounding, 3NER, 500 A / 10 s, LRG
- Northern European industrial plant — HRG system, 1NER, continuous current, active remote monitoring
- Backup power centre, data centre — generator neutral, 1NER, passive monitoring integration

NOMENCLATURE EXAMPLE

NERC - 5 - 18.5 - 13.5 - 17 - CG - 22R **3**

22R	Resistance value in Ohm	
CG	GRID	CG NCG2 LAG
17	Internal Insulation	17.5 24 36
13.5	Length	13.5 16
18.5	Width	18.5 28.5
5	Number of floors	
NERC	Neatral Earthing Resistor Cabinet - HV	
3	Cabinet Dimension Ref.	1 2 3

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