Technology (continued)

Hubs

Drive Trains

Generators

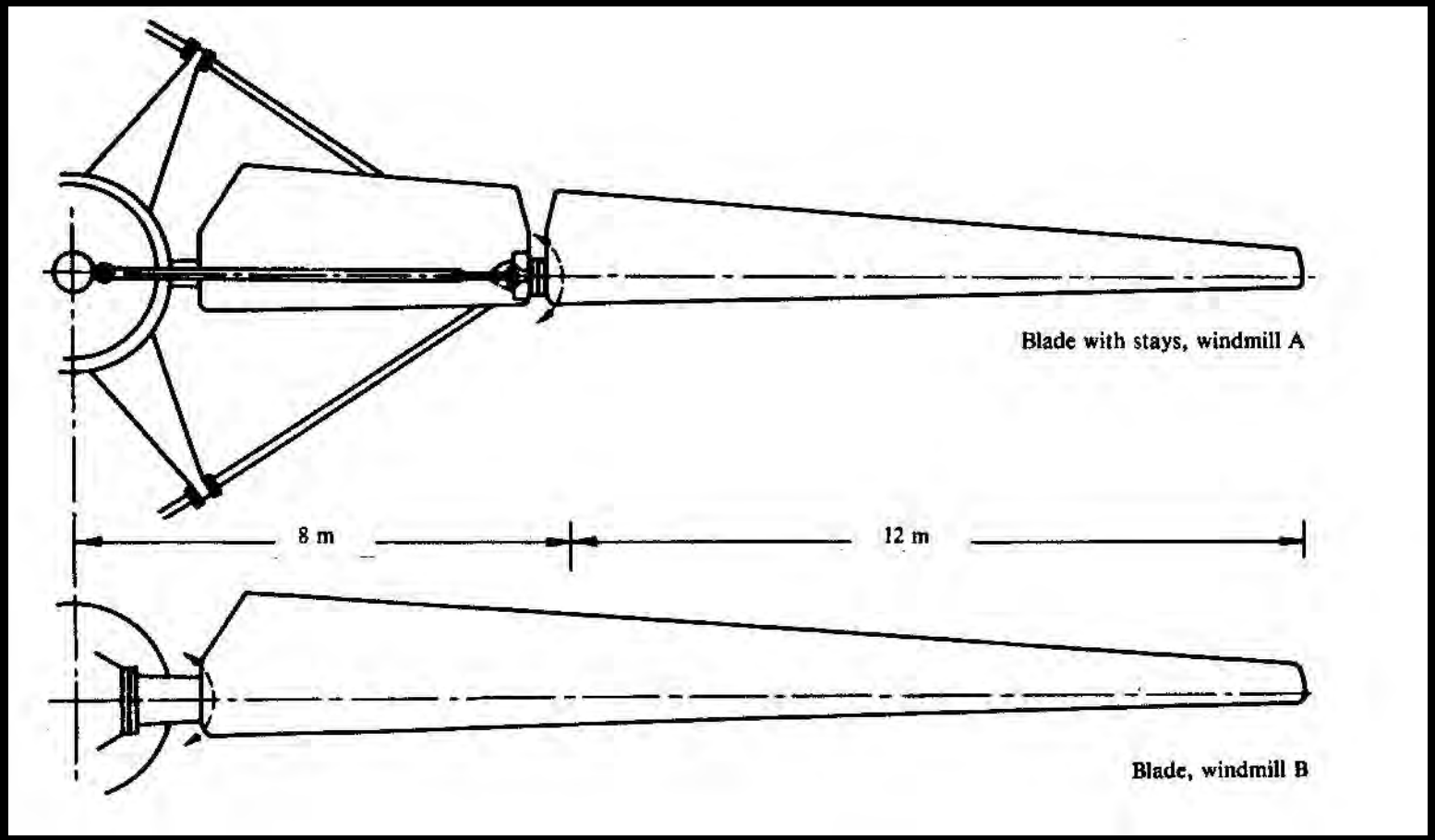
Towers

Foundations

Lightning Protection

Obstruction Marking

Hubs
Struts & Stays



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Hubs
Teetered-Delta 3-Butterfield

Paul Gipe, wind-works.org

ESI 80, Palm Springs, CA

Hubs
Teetered-Pitch Linked

Windflow 500
Gebbies Pass, NZ

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Hubs
Cantilevered

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Hubs
Fixed (But Adjustable) Pitch

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Hubs
Variable Pitch

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Drive Trains
Traditional Danish

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Drive Trains
Main Shaft-Traditional

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Drive Trains
Integrated (Small-Medium)

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Drive Trains Integrated (Large)

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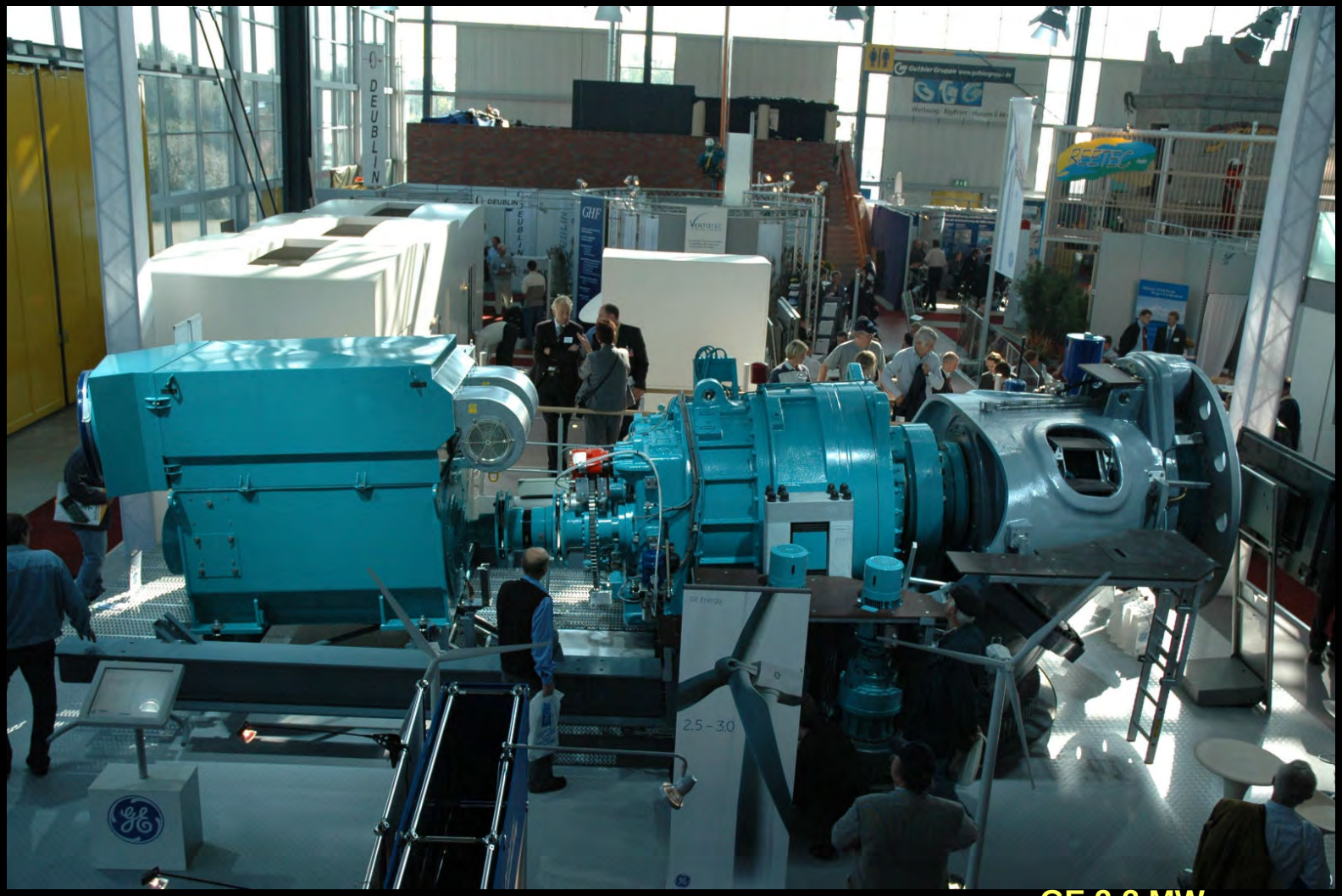
New Drive Trains



GE 2-3 MW

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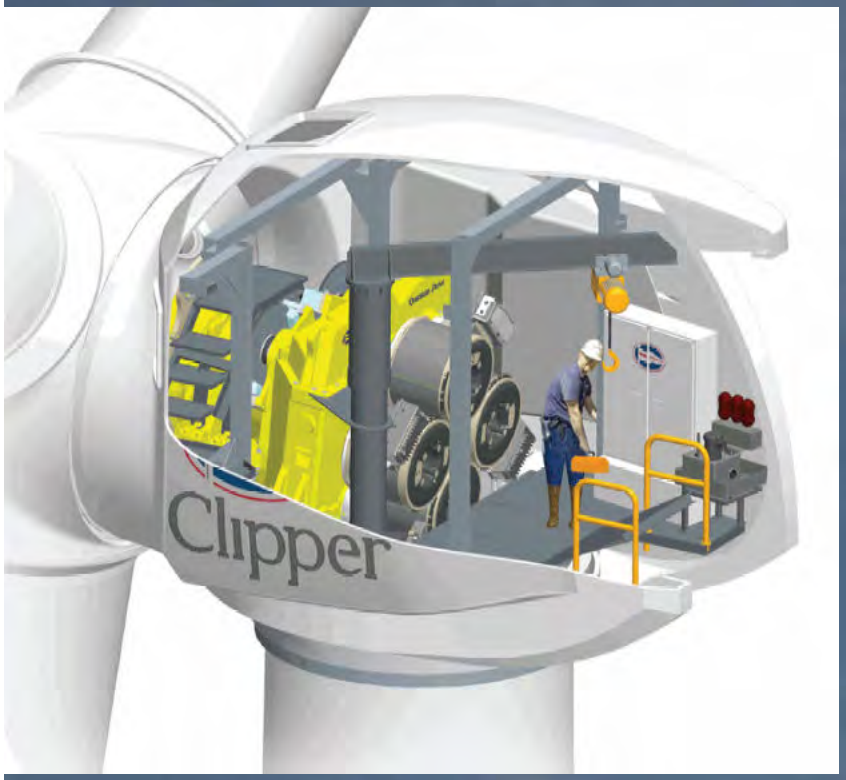
Drive Trains
Multiple-Output Gearboxes



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Buffalo, New York

Generators Dual-Induction

- Dual Speeds
- Simple
- Rugged
- Cheap

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Generator Pole Switching (RPM)

	50 Hz	60 Hz
4-pole	1500	1800
6-pole	1000	1200

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Generators
Wound-Rotor (Doubly-Fed)

Paul Gipe, wind-works.org

Generators
Direct-Drive (Large)

Paul Gipe, wind-works.org

© Enercon

Generators-Variable Speed

- **Better Performance**
  - **Mostly Hype**
- **Lower Loads**
  - **Major Plus in LargeTurbines**
- **Ability to Correct Power Factor**
- **More Expensive**
- **More Complex**
- **And, Don’t Forget the “Patent”**

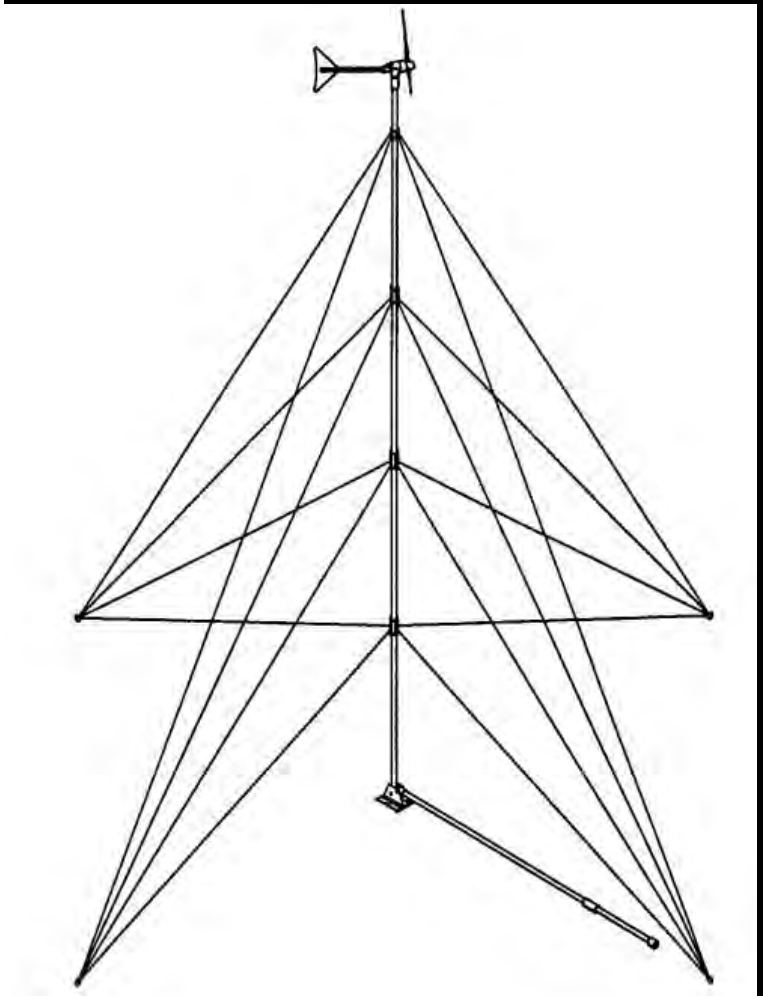
Generators-Variable Speed

- “Opti” Slip (10%)
- Doubly Fed Generators
  - Widely Used in Germany
  - Inverter Handles Only a Portion of Power
- Full Variable Speed
  - Inverter Handles Full Power
  - Full Benefits of Variable Speed
  - Enercon, Lagerwey, & PMGs

Towers

- **Guyed**
  - **Small Turbines**
  - **Large Turbines**
- **Freestanding (Cantilevered)**
  - **Lattice**
    - **Small Turbines**
    - **Large Turbines**
  - **Tubular**
  - **Concrete**
- **Hinged**

Towers-Guyed
Small Turbines



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Towers-Guyed Lattice
Small & Medium Wind Turbines

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Towers-Guyed Large Wind Turbines

Paul Gipe, wind-works.org

Towers-Lattice

Paul Gipe, wind-works.org

© Nordex

Towers-Lattice

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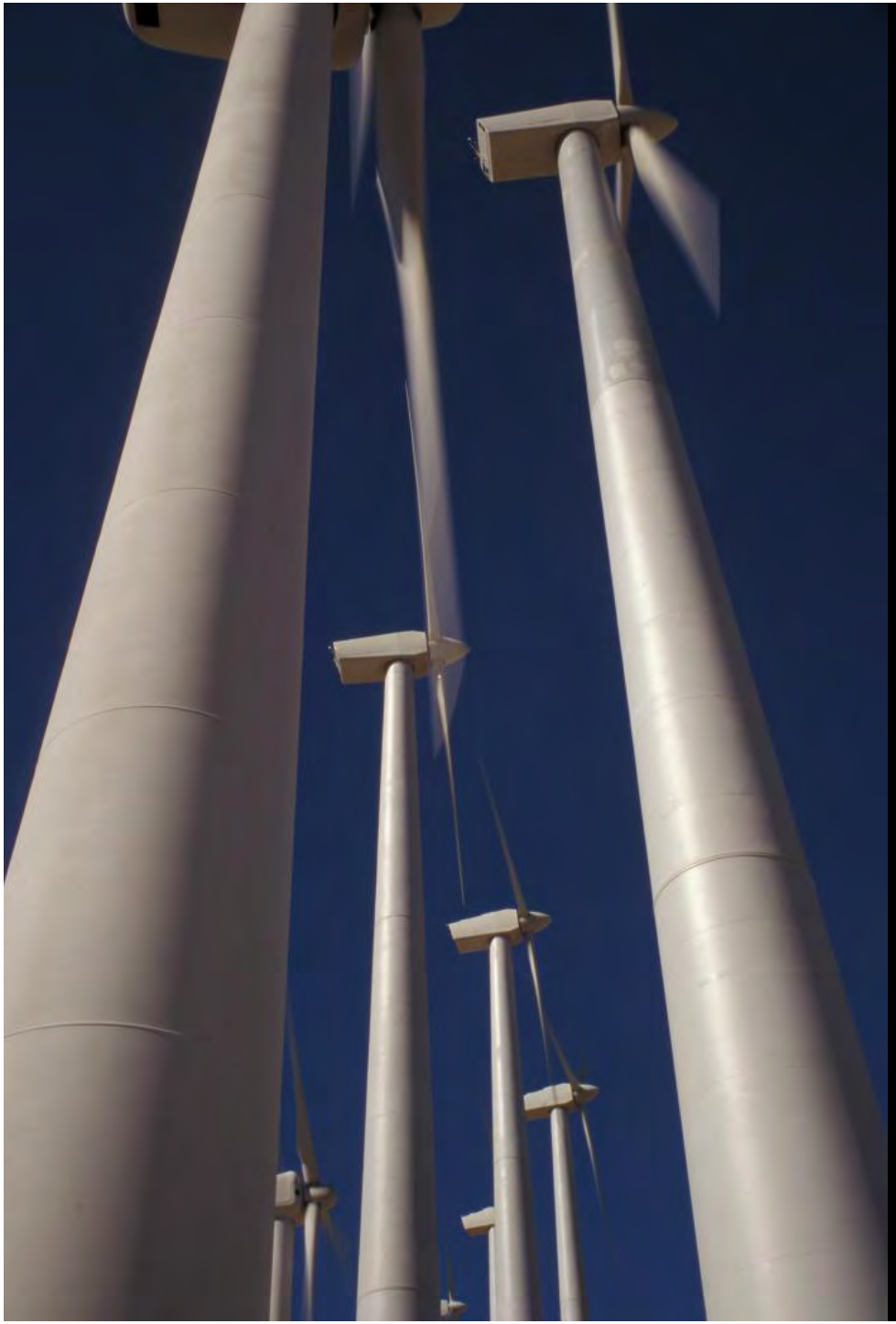
Towers-Tubular Small Turbines

Paul Gipe, wind-works.org



Towers-Tubular Medium & Large Wind Turbines

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Towers-Concrete

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Towers-Hinged Small Turbines

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Towers
Pendant Cables & Raceway

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Foundations

- **Piers**
  - **Lattice Towers**
- **Spread Footing**
- **Monopile**
  - **Solid**
  - **Hollow with Fill**

© Goldenstedt

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Foundation Monopile Hollow with Fill

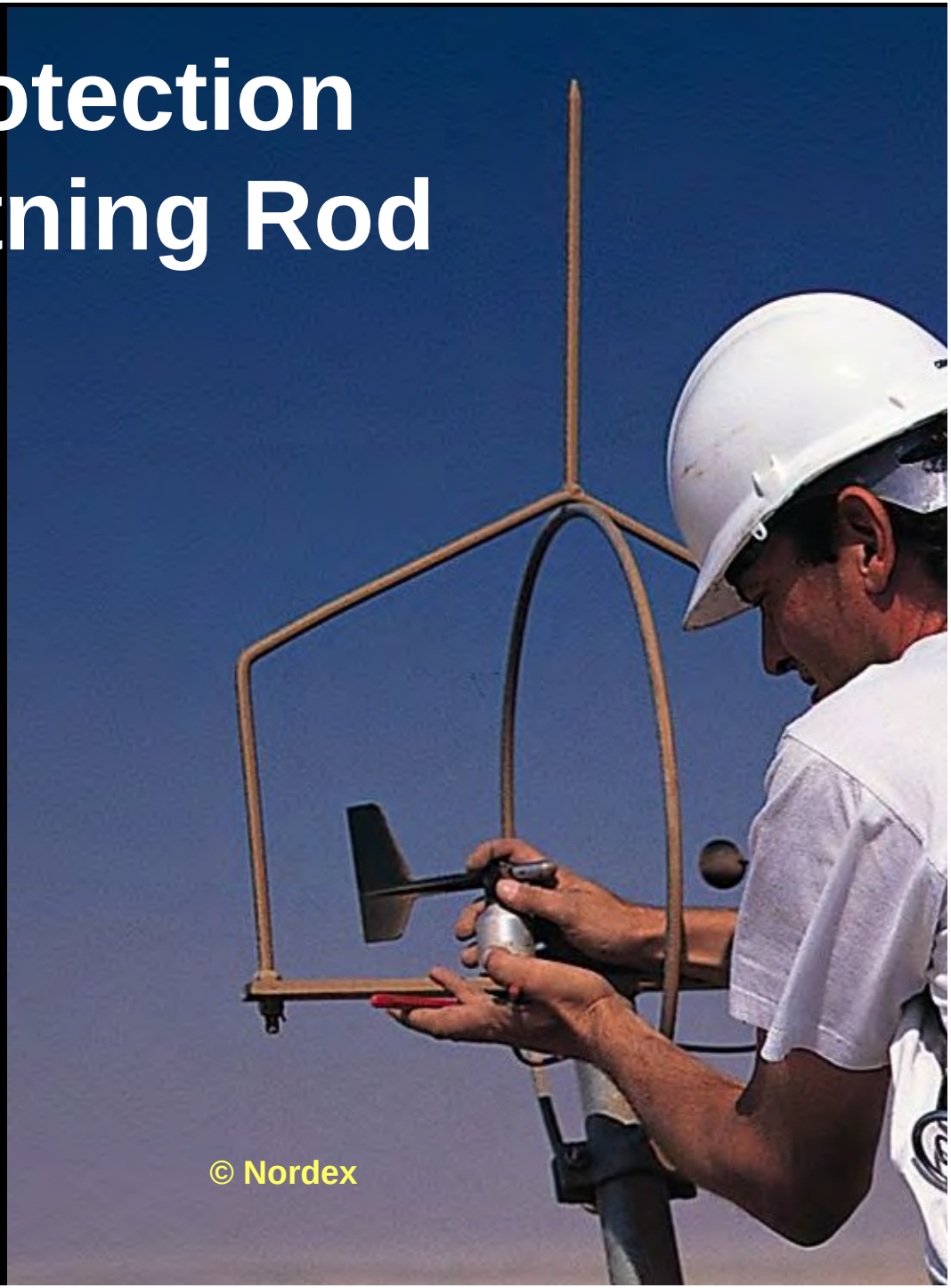
© Neal Emmerton

Paul Gipe, wind-works.org

Foundation Bolts

Paul Gipe, wind-works.org

Lightning Protection
Nacelle Lightning Rod



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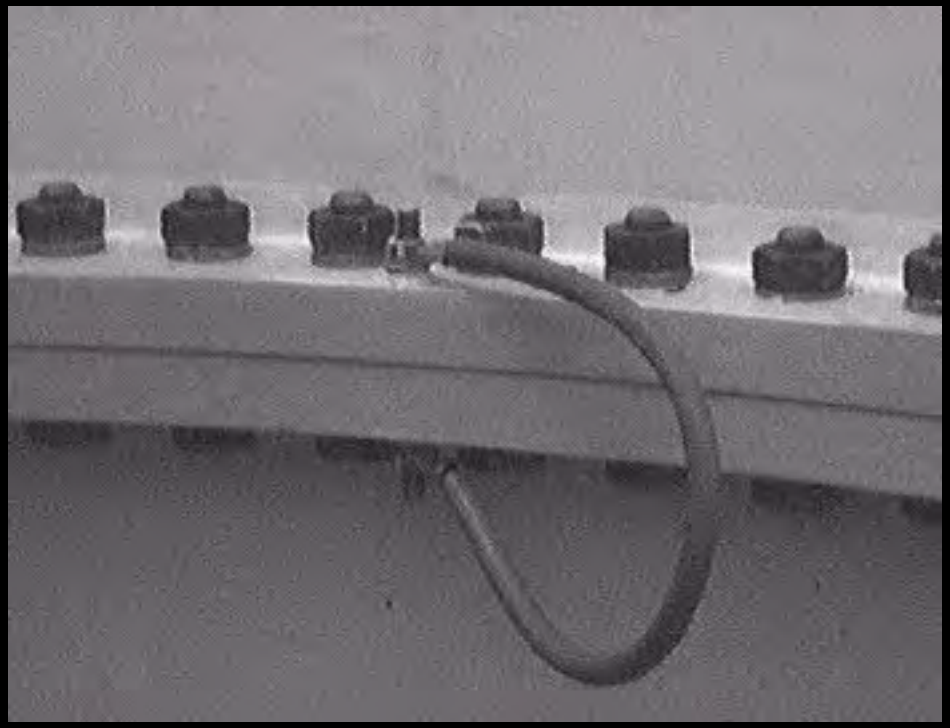
Lightning Protection Tower Section Jumpers



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Obstruction Marking

- **Height Limits**
  - 200 ft USA
  - 100 m Europe
- **Lights**
  - Red (night?)
  - Strobe (Day)
  - Impacts
- **Painting**

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Obstruction Marking

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Operations & Maintenance

- **Large Turbines**
  - Formerly by Quarter
  - Now Once/year
- **Small Turbines**
  - Once/year
- **Large Turbines**
  - Complex & Rotating Schedules
  - Visual Inspections
  - Moving Parts
- **Electronic Controls**
  - Largest Single Cause of “Nuisance” Trips

Good Housekeeping

- **Little Items Make a Big Difference on a Million-Dollar Wind Turbine!**

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Operations & Maintenance
Check Welding

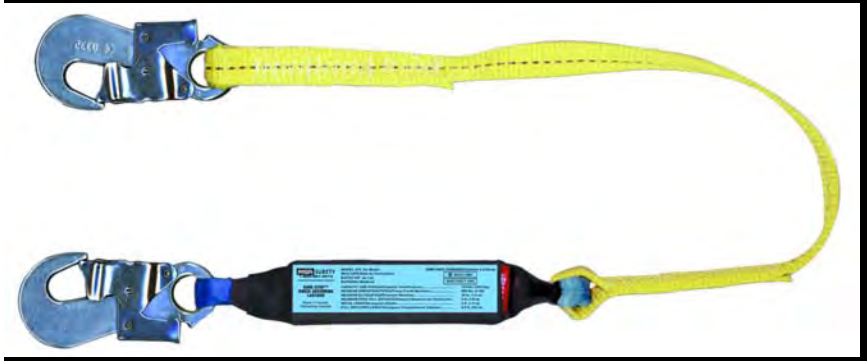
© Lagerwey

Operations & Maintenance

- Condition Monitoring
  - Large Turbines
- w/o Condition Monitoring, No Insurance
- w/o Insurance, No Financing
- Enercon “Partner” Program
  - Other Manufacturers Following Suit

Fall Protection

- Body Harness
- Shock-Absorbing Lanyard
- Double-Acting Snap Hook
- Positioning Belt is Only for Positioning



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Safety

- Helmet
- Gloves
- Harness
- Radio

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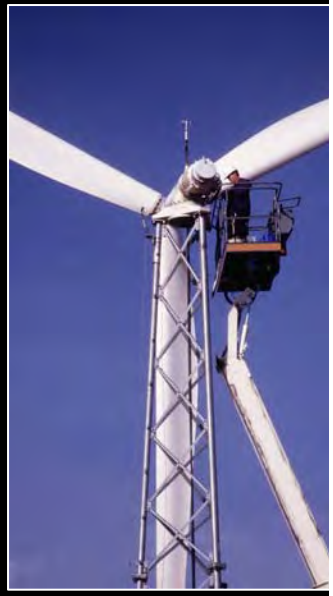
Aerial Lifts



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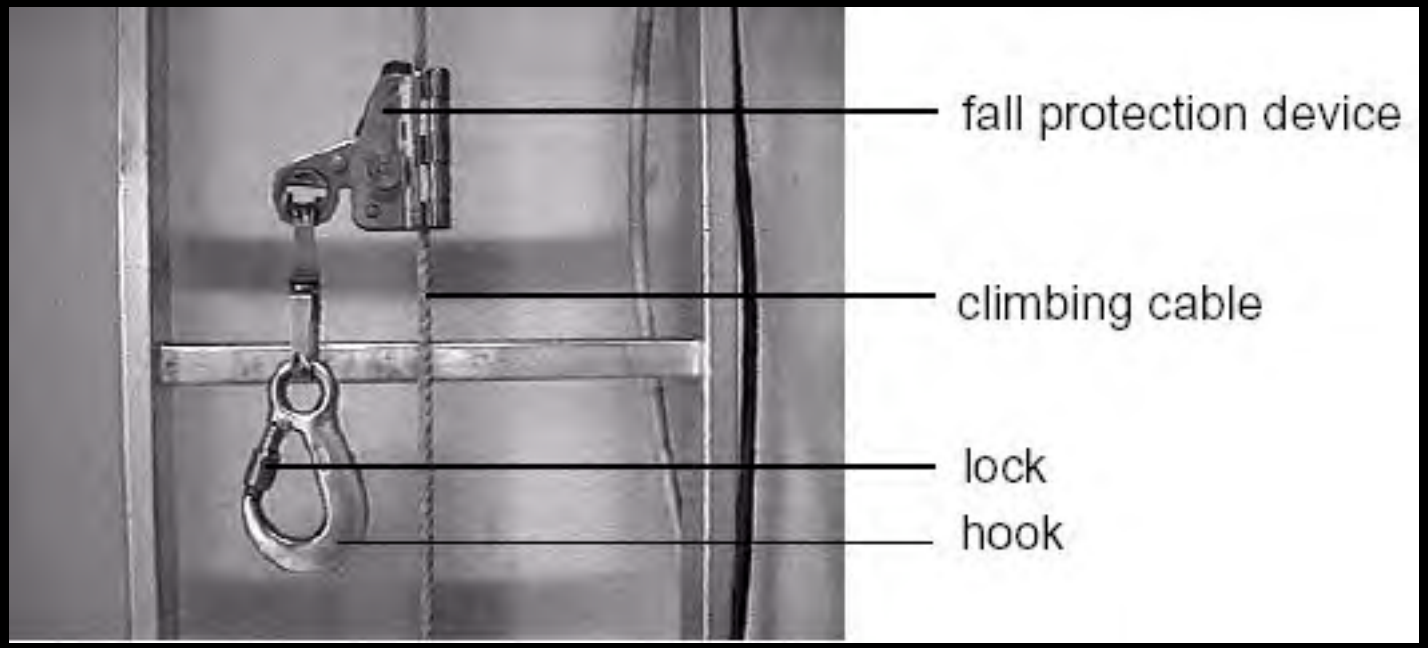
Ladder Fall Protection



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Ladders

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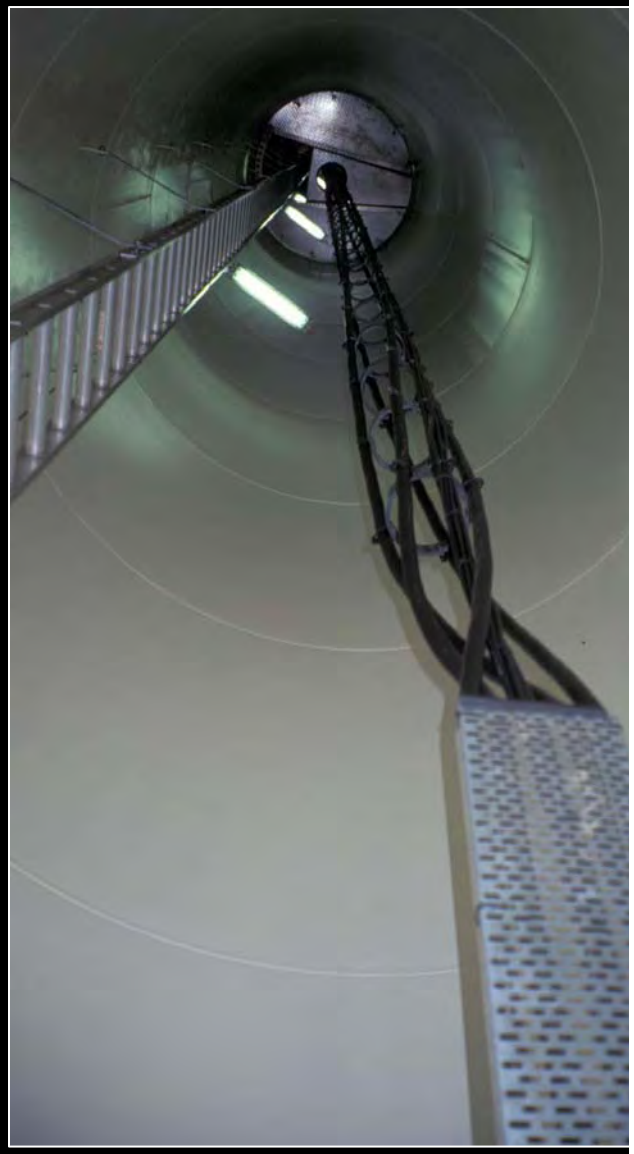

Steps

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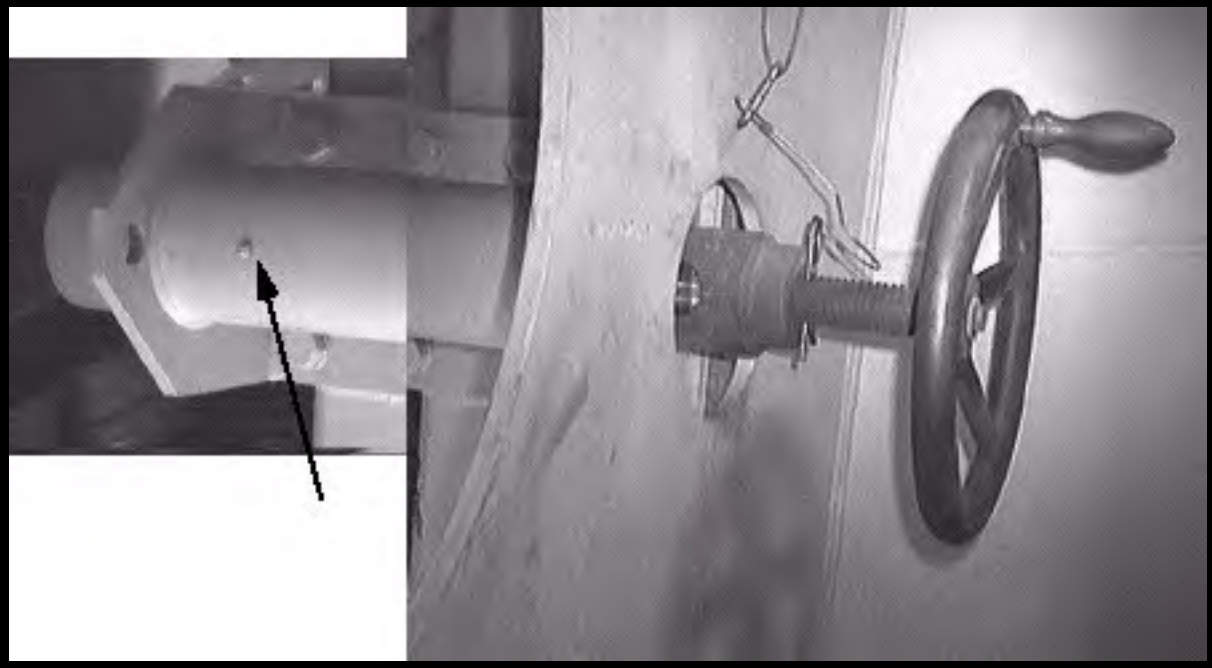
Secure Rotor Locking

Rotor Hub



© Lagerwey

Secure Rotor Locking

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Secure Rails & Attachments

© Nordex

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Access Doors

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Tararua, NZ

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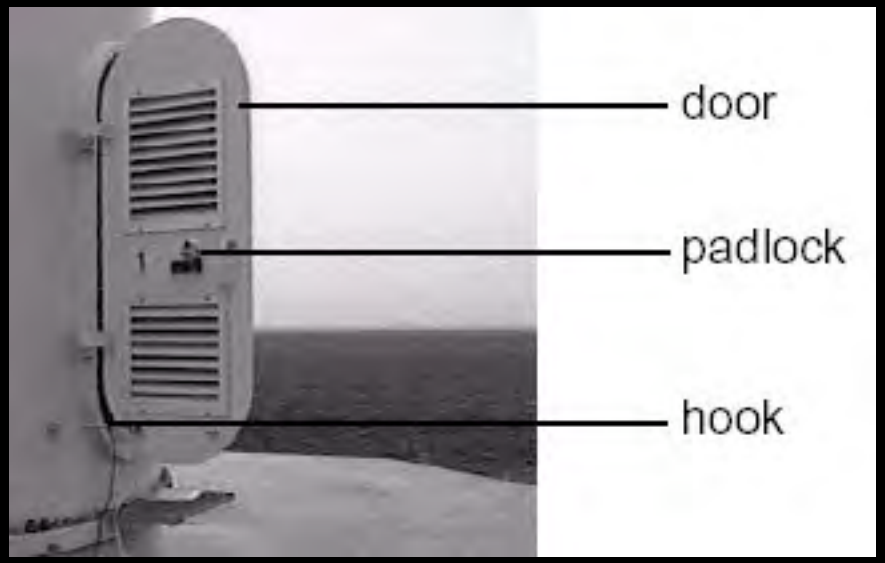
Secure Access Doors

It's Windy Out There

- **Lock to Prevent**
  - **Unauthorized Access**
- **Latch to Prevent**
  - **Door Closing**
- **Interior Release**
  - **To Prevent Confinement**
- **Ventilation Louvers**



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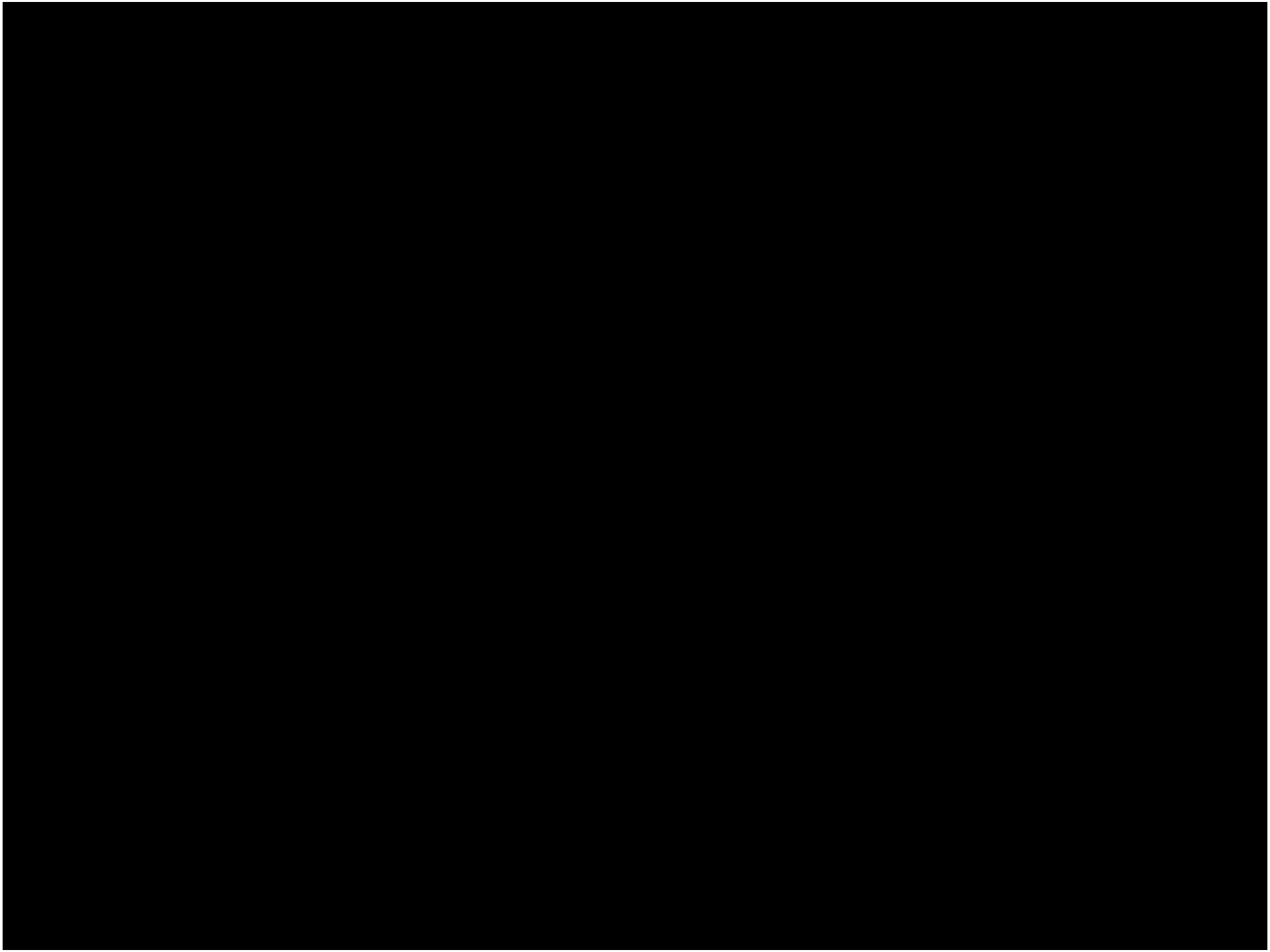
Safety . . .

- Anti-Climb Guards
- Shaft Guards
- Two-Person Crews
- Regular Reviews
- Myth Busting
  - “Never Fall Ascending”
  - “Want to Jump Free”

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