Explosive Cladding of Metals

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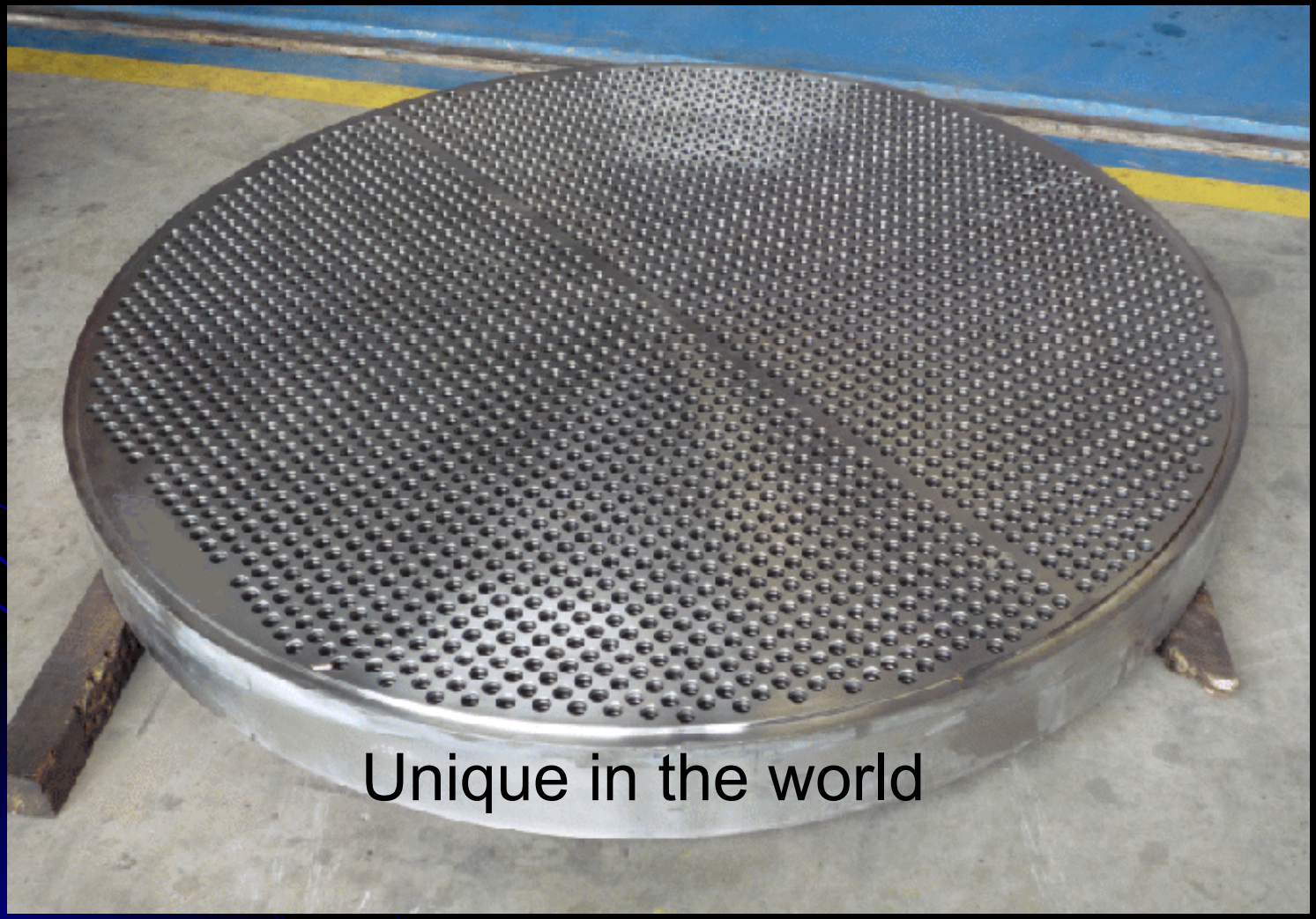
www.smt-holland.com

and www.triplate.com

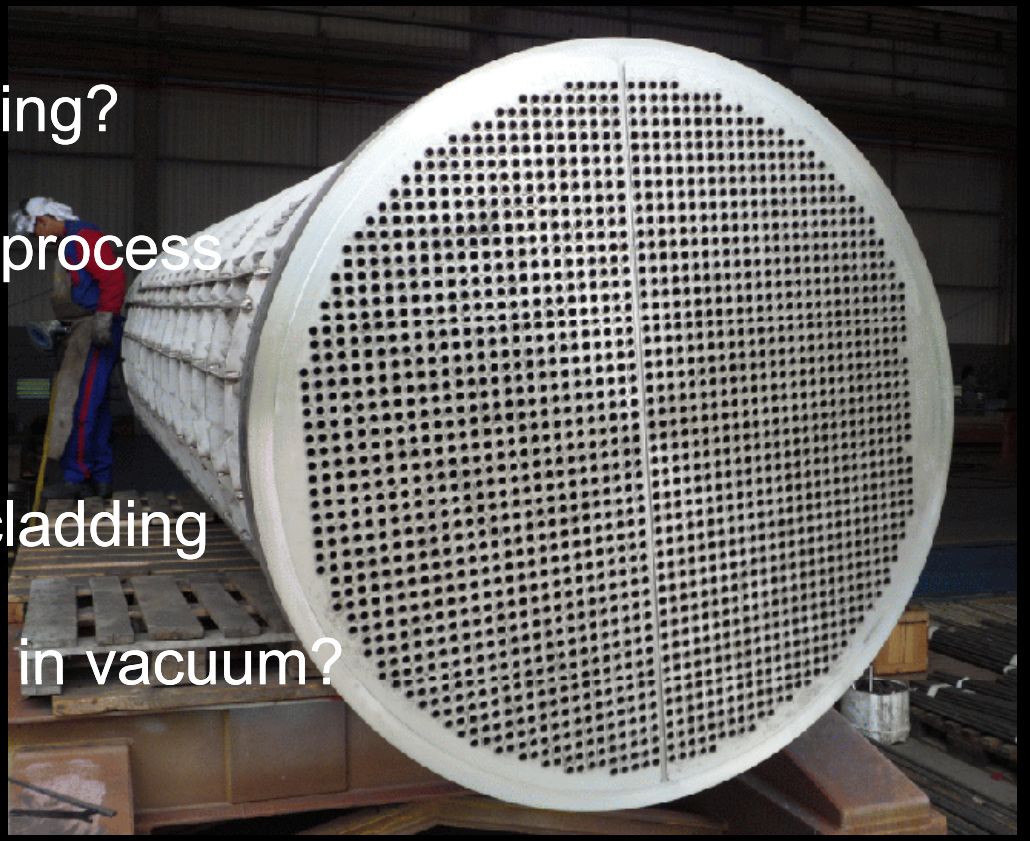
Explosion bonded clad plates by means of vacuum technology



Unique in the world

Introduction

- Introduction of SMT
- What is explosive cladding?
- The explosive cladding process
- Applications
- Advantages explosive cladding
- Why explosive cladding in vacuum?
- Quality control
- Processing cladmaterial and conclusion

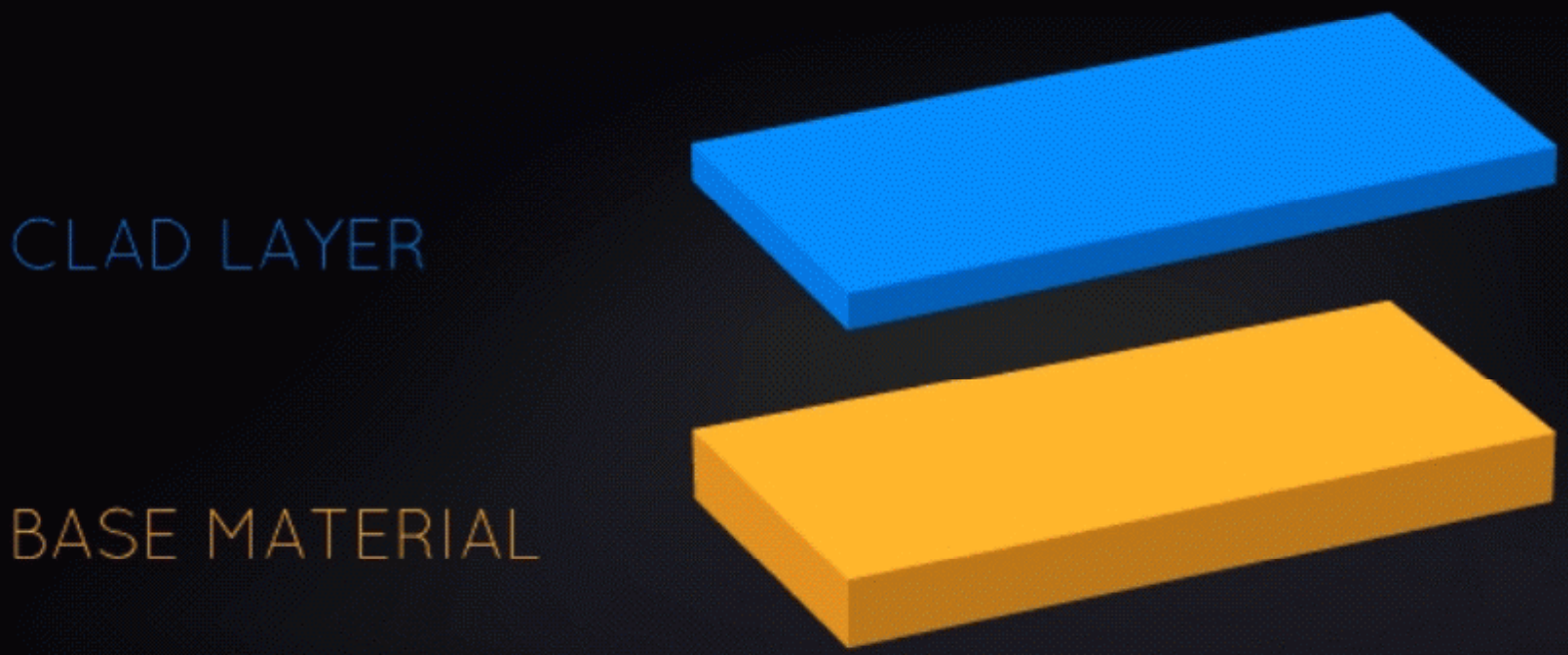


Introduction SMT

- Starting vacuum technology in 1985
- Worldwide active
- Production in 3 vacuum chambers
- Activity: explosive cladding
- Additional value such as technical recommendations and metallurgical support

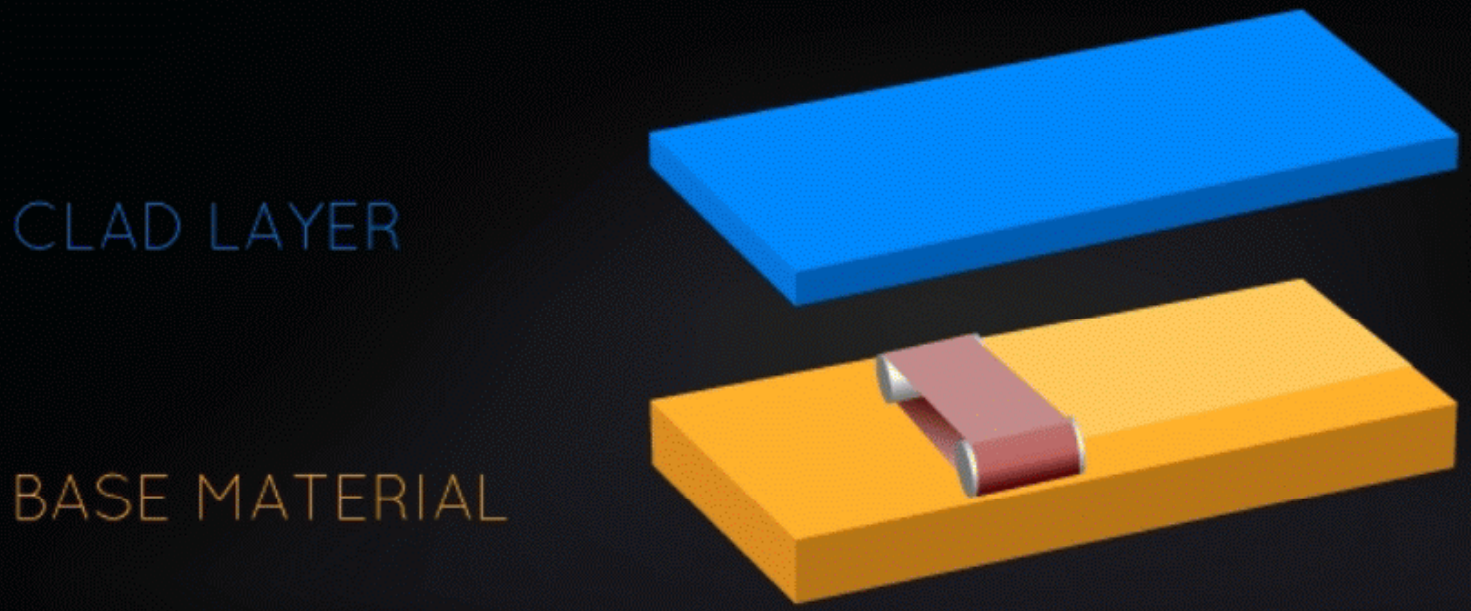
Material Inspection

STEP 1: PLAIN MATERIAL INSPECTION



Carbon steel grinding and preparing

STEP 2: GRINDING

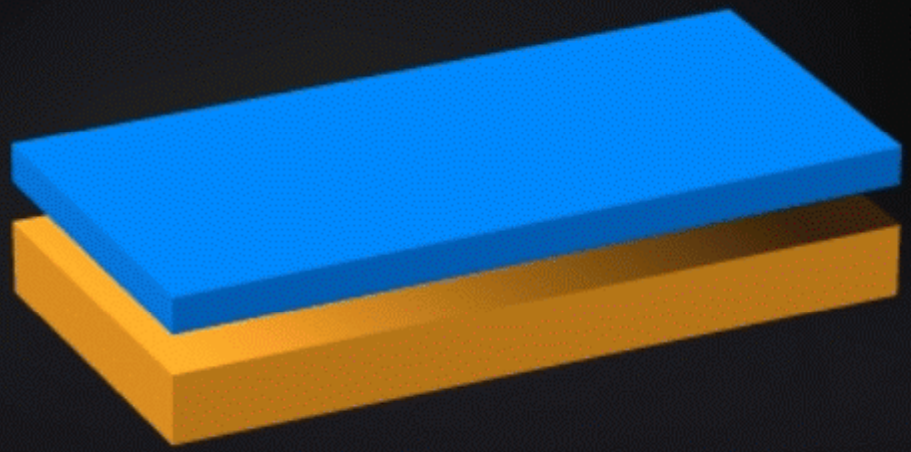


Set-up with stand-off space

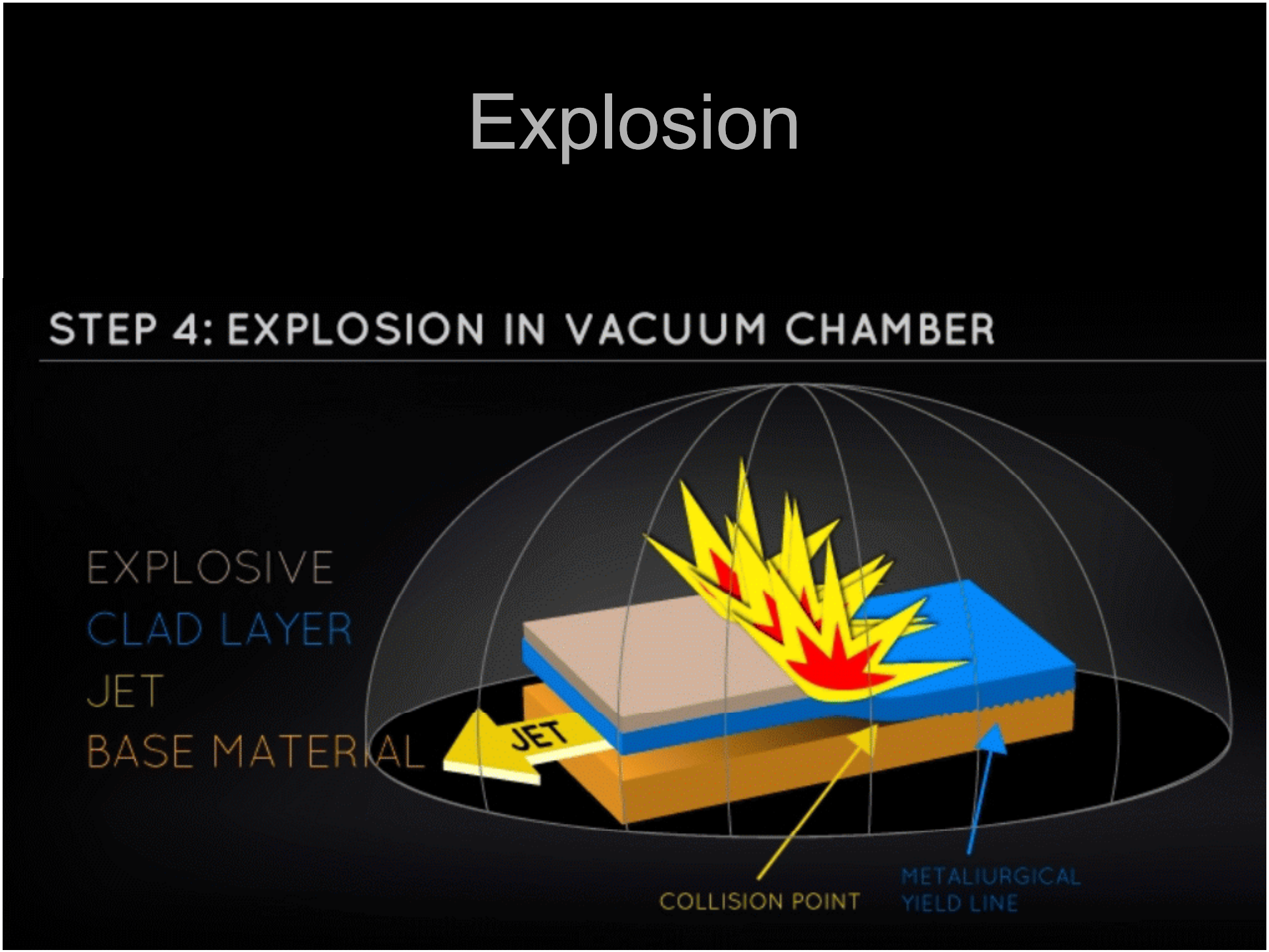
STEP 3: SET-UP

CLAD LAYER

BASE MATERIAL

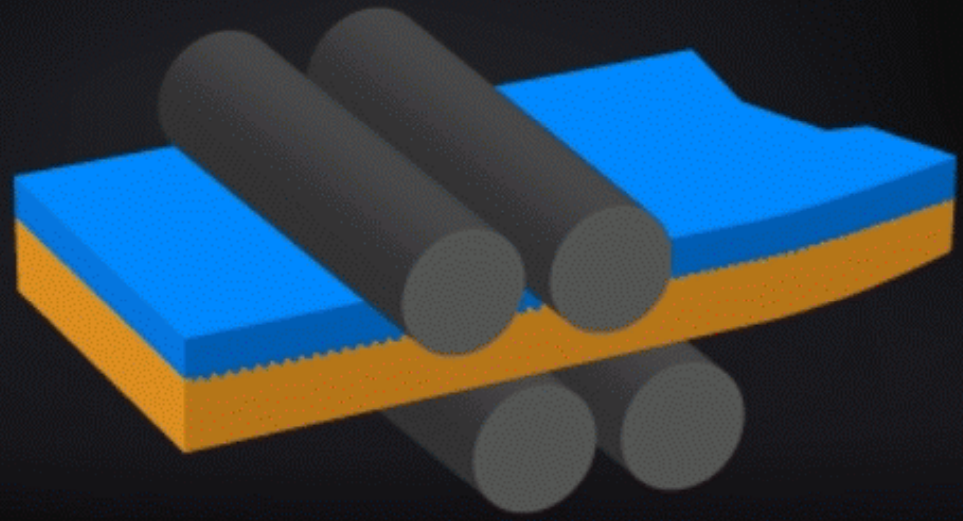


Explosion


STEP 4: EXPLOSION IN VACUUM CHAMBER
EXPLOSIVE
CLAD LAYER
JET
BASE MATERIAL
JET
COLLISION POINT
METALIURGICAL
YIELD LINE

Flattening by rolling or pressing

STEP 5: FLATTENING & CUTTING

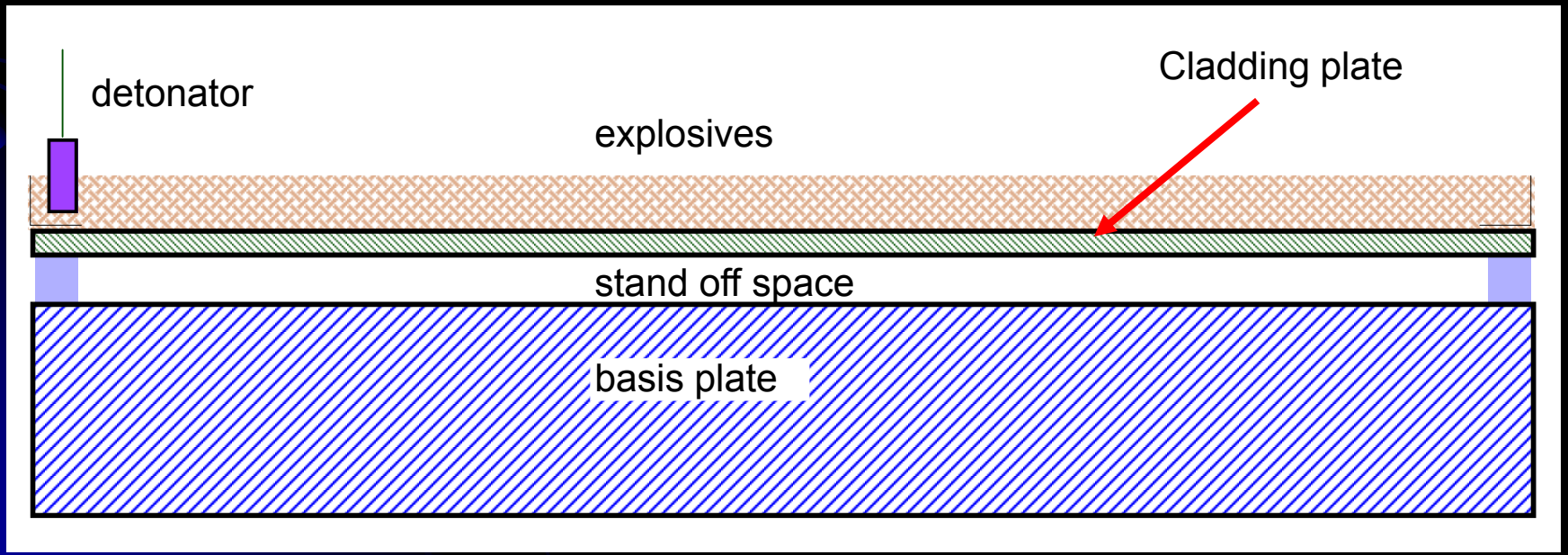


US and mechanical testing

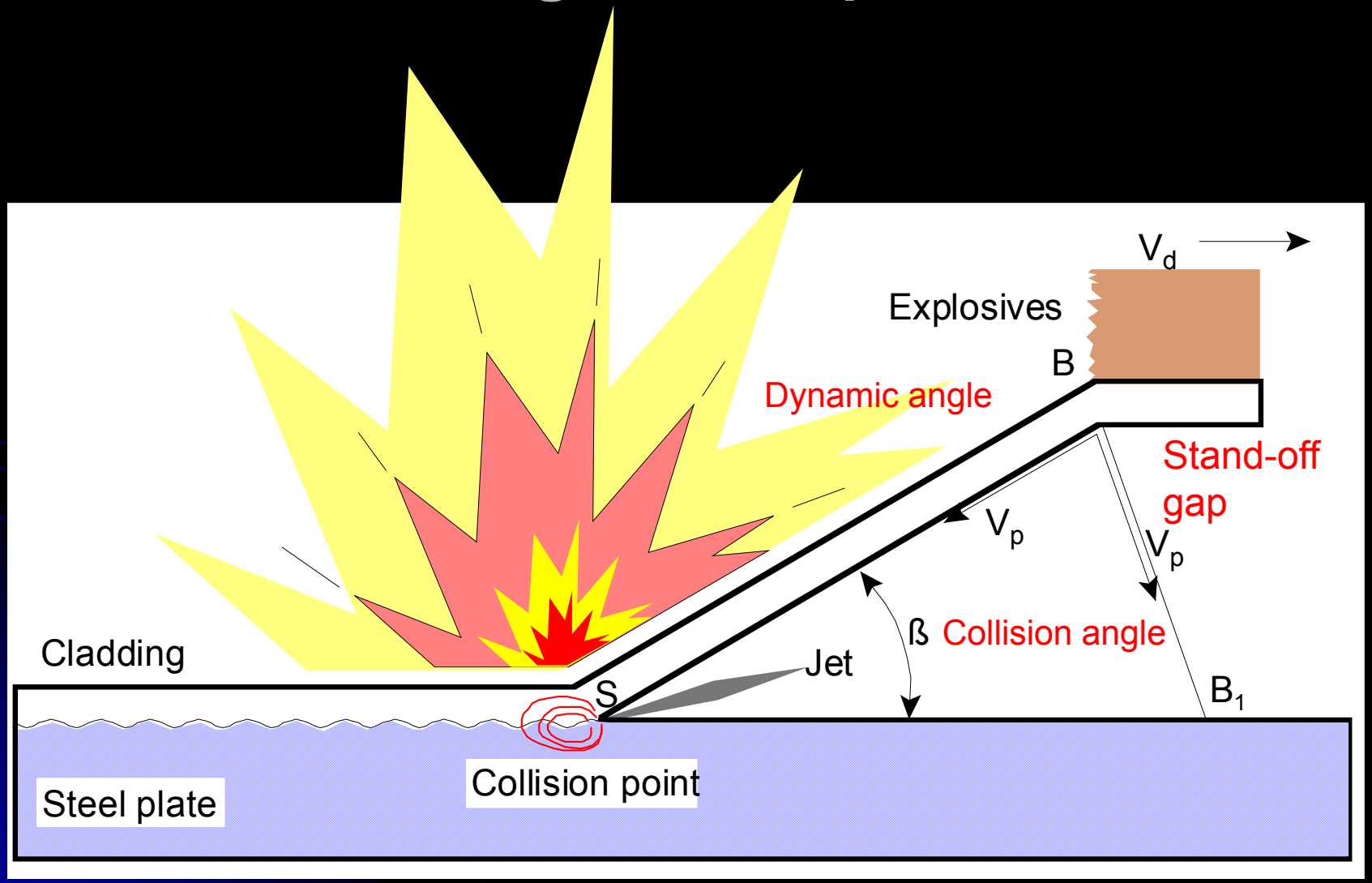
STEP 6: INSPECTION & TESTING

The explosive cladding process

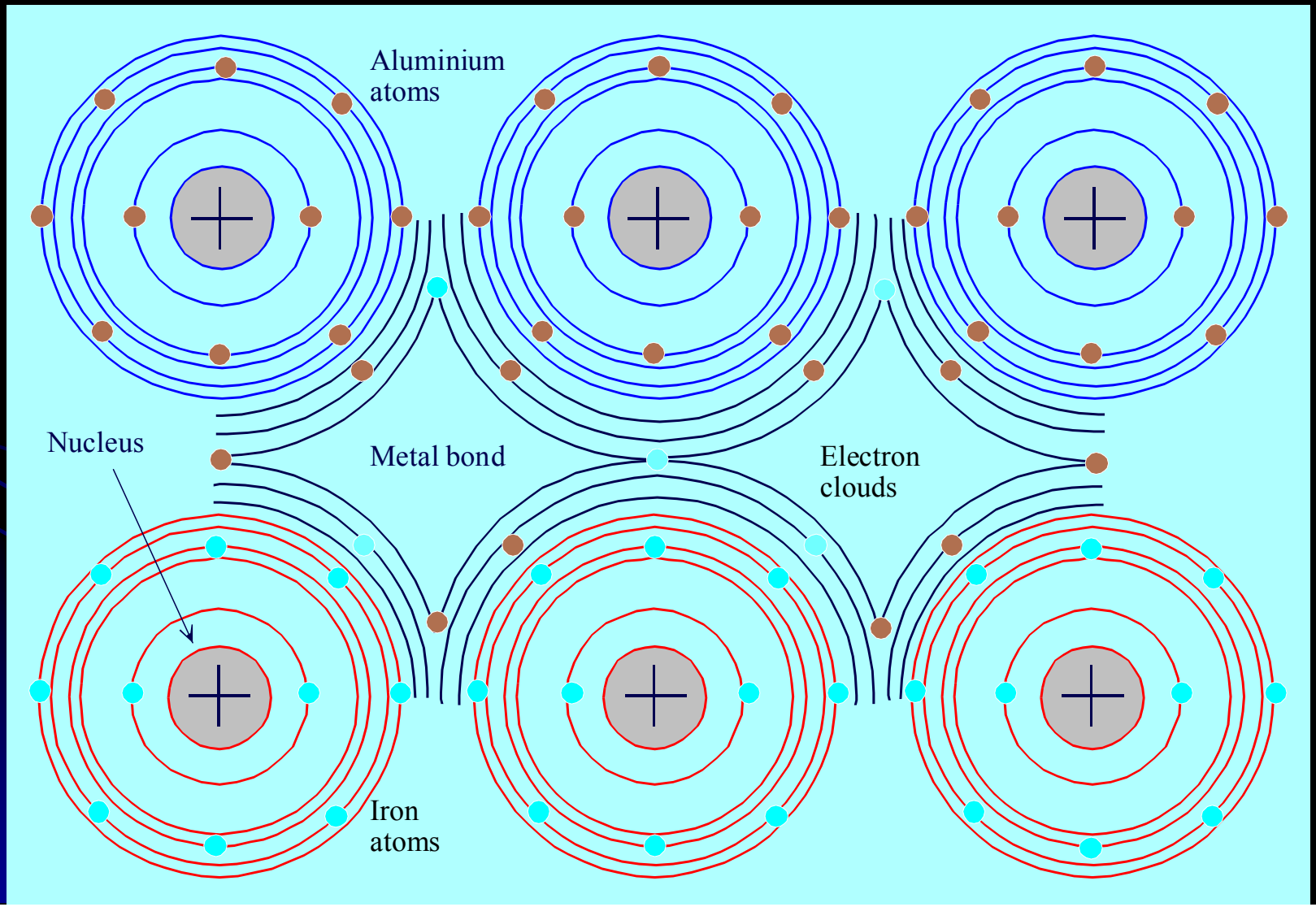
- Grinding of the surfaces
- Set-up
- Preparation of explosion process
- Explosion welding



The explosive cladding process during a snapshot

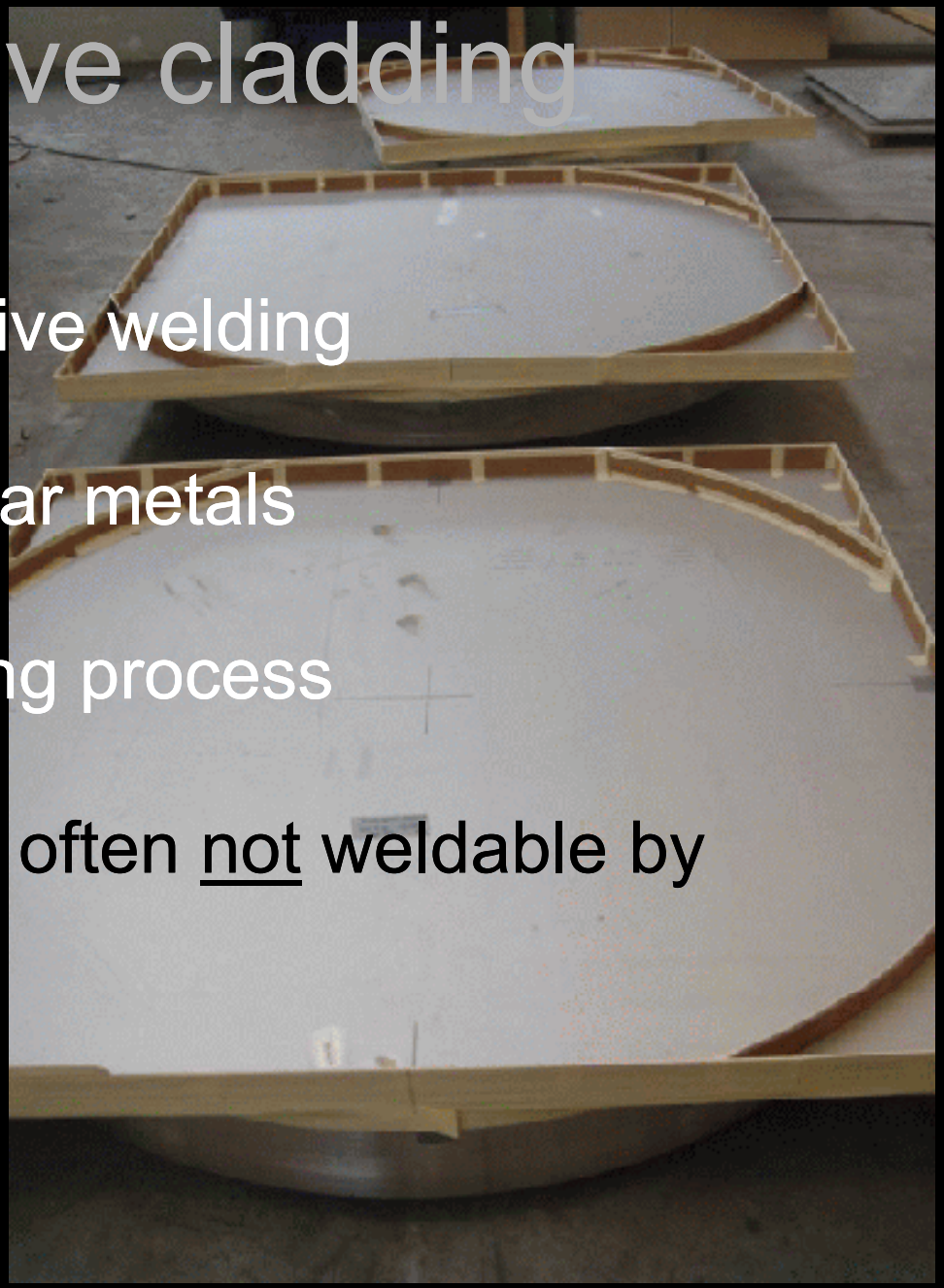


Mechanism of atomic bond



Explosive cladding

- Synonym for explosive welding
- two or more dissimilar metals
- cold pressure welding process
- metals conventional often not weldable by thermal processes



Process configurations

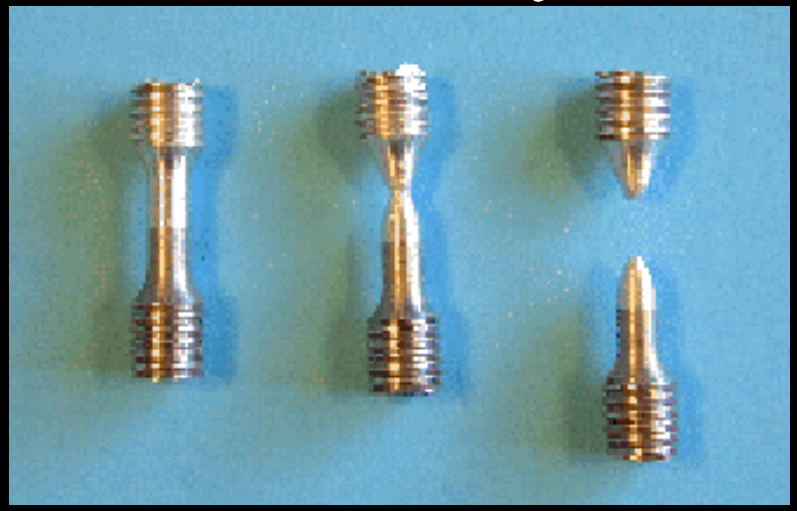
- **Possible process configurations:**
  - Flat plates (square and rectangular)
  - Round discs (heads and tubesheets)
  - Pipes, long welding neck flanges
  - Pump shafts

Dimensions and capacity

- Maximum sizes and capacity:
  - Maximum Length: ± 14 meter
  - Maximum width: ± 4 meter
  - Maximum total area: 30 m^2
  - Lifting capacity 30 metric tons
  - Base material thickness: 10 - 500 mm
  - Clad material thickness: 1 - 25 mm

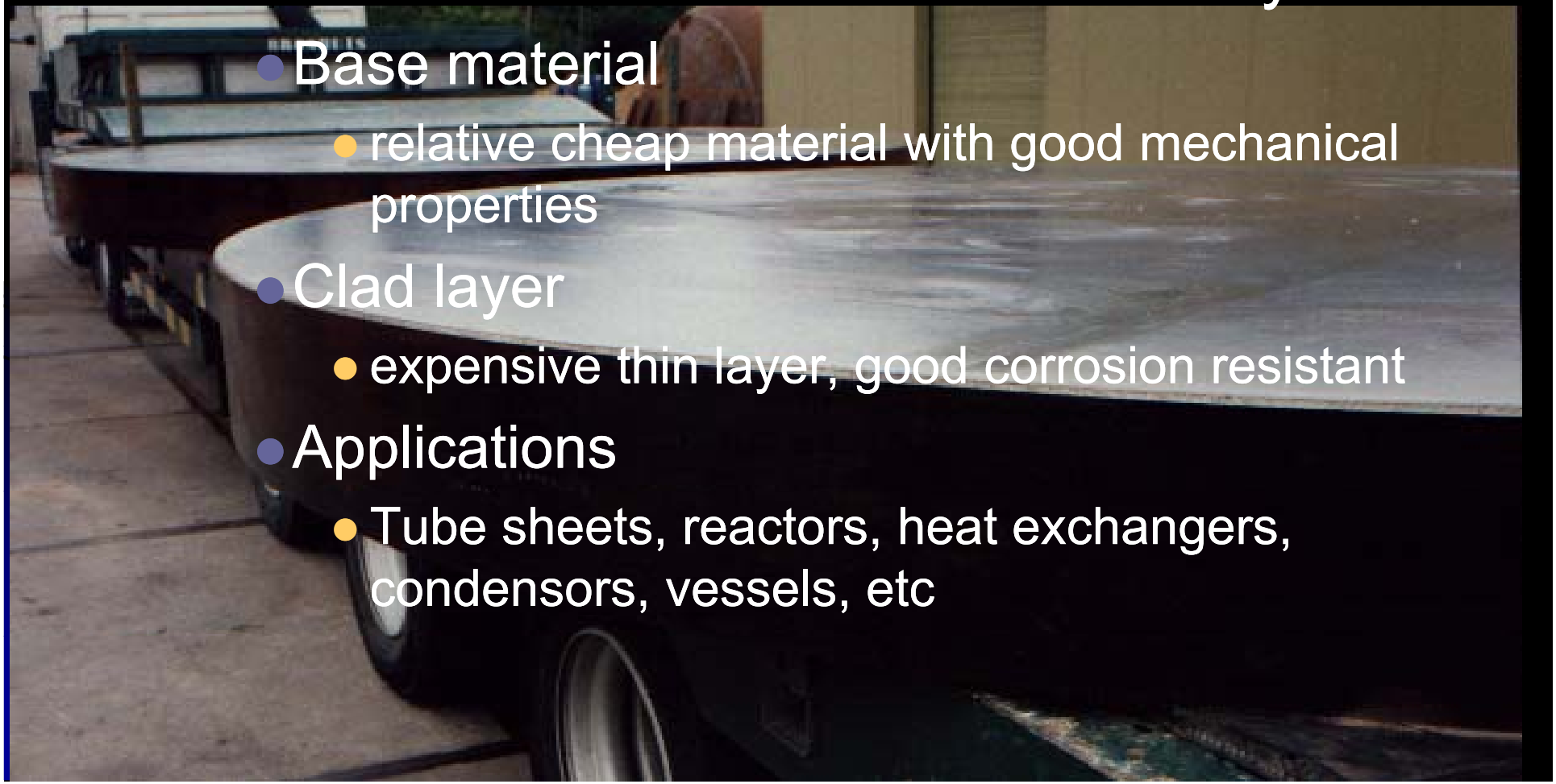
Properties metal joint

- Properties of the explosive metal joint
  - Homogeneous integral of two or more dissimilar metals
  - Joint bond stronger than the weakest material
  - Original metal properties are remaining
  - Good thermal and electrical conductivity
  - Oxide free
  - Atomic bond
  - No crevices



Applications

- Chemical and Petrochemical Industry
  - Base material
    - relative cheap material with good mechanical properties
  - Clad layer
    - expensive thin layer, good corrosion resistant
  - Applications
    - Tube sheets, reactors, heat exchangers, condensors, vessels, etc



Metal combinations

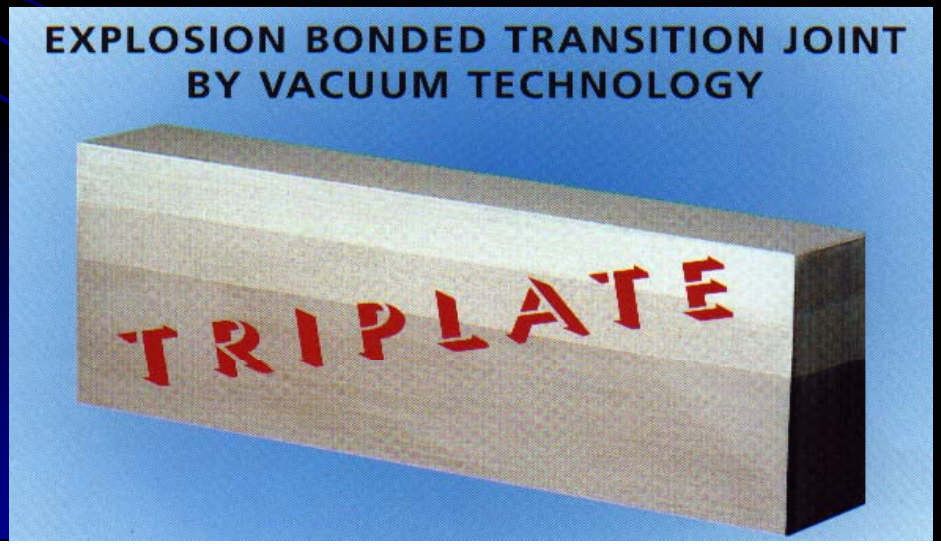
- Often used metal combinations:
  - Titanium / Carbon steel
  - Titanium / Stainless Steel
  - Aluminium Bronze / Carbon steel
  - Stainless Steel / Carbon steel
  - Nickel + Alloys / Carbon Steel
  - Hastelloy / Carbon Steel
  - Duplex - Super Duplex / C-steel
  - Aluminium / Carbon steel

Transition joints

- Marine applications
  - Triplate for shipbuidling and offshore
- Electrical applications
  - ETJ’s Electrical Transition Joints

Marine applications

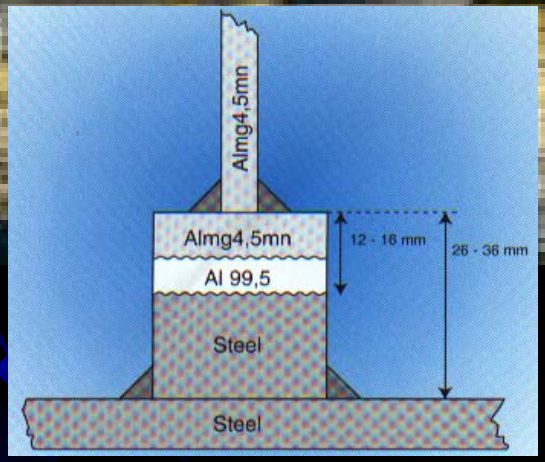
- Triplate® : Shipbuilding
  - Aluminium/Steel transition joints
  - Base material: Carbon Steel
  - Interlayer: Aluminium 99,5
  - Super layer: AlMg4,5Mn



Queen Mary II

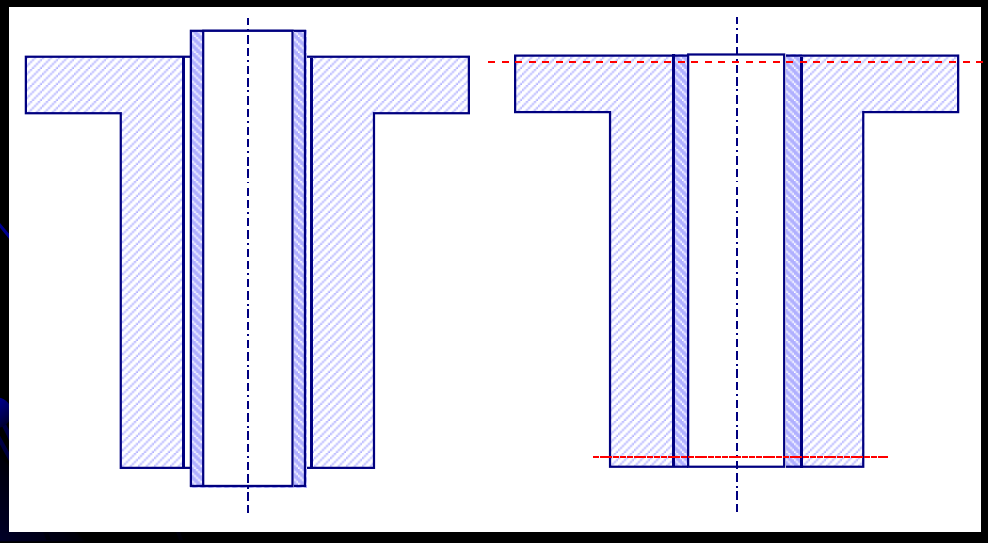
The processing of Triplate®

- Cutting into bars from tested clad plates
- Straightening and marking
- Enables to weld the aluminium superstructure to the steel hull
- Examples: mega yachts, cruise vessels, ferries, tenders, fishing vessels



Applications

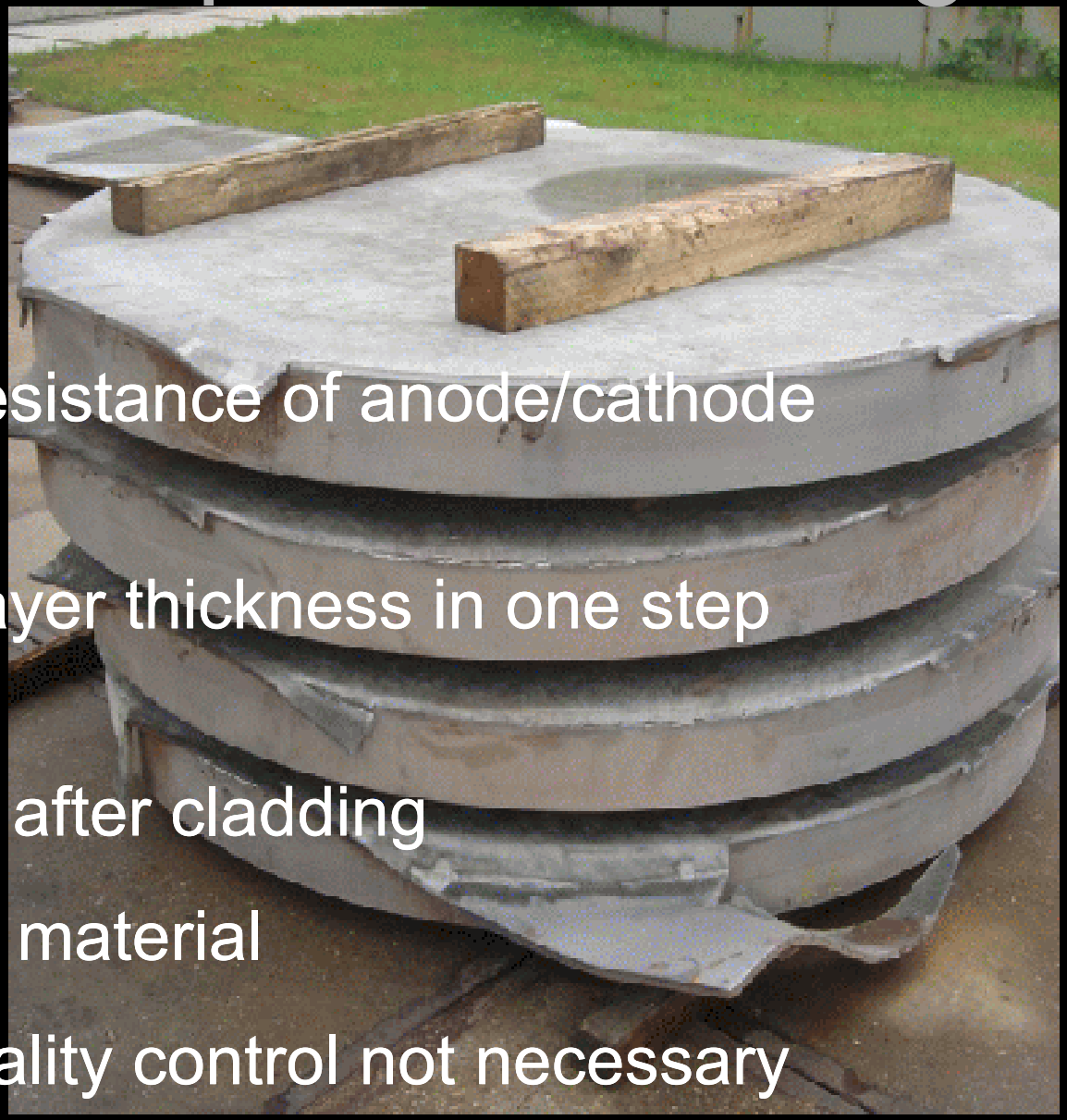
- Inside cladding of pipes / LWN
  - Thickness clad layer: 3-4 mm
  - Wall thickness pipe piece: minimum 40 mm
  - Internal diameter: 25 - 1200 mm
  - Length: max. 1 meter



Advantages Explosive Cladding

- Metal combinations possible which are conventional impossible to weld i.e.: Ti/Steel, Cu/Al, Al/Steel etc.
- Saves costs: thin layer of expensive material cladded on a thicker layer of cheap material
- Original metal properties remains
- Joint bond stronger than the weakest material

Advantages explosive cladding

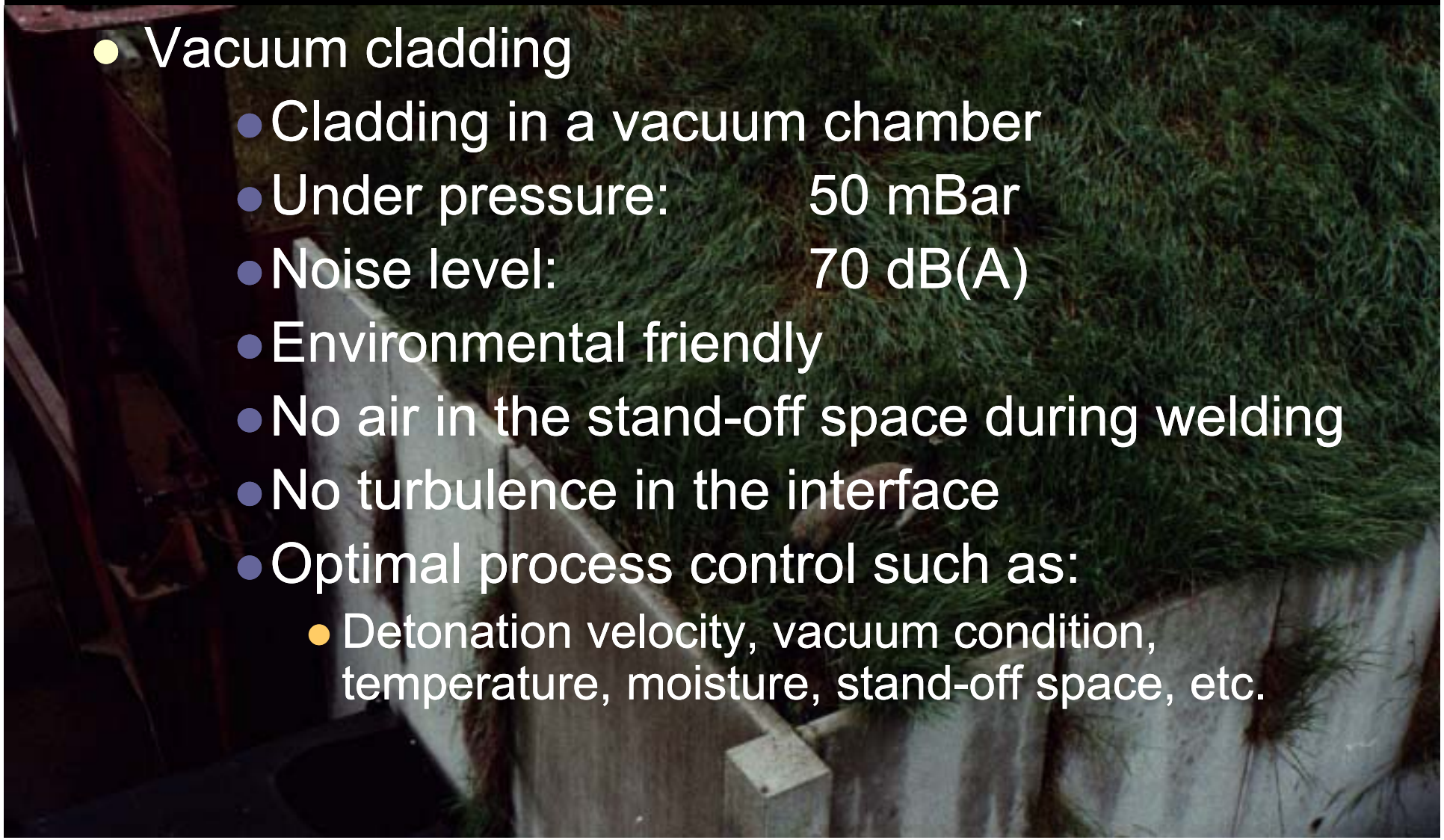


- Low electrical resistance of anode/cathode blocks
- Required clad layer thickness in one step realized
- Smooth surface after cladding
- Save expensive material
- Intermediate quality control not necessary

Why explosive cladding in vacuum?

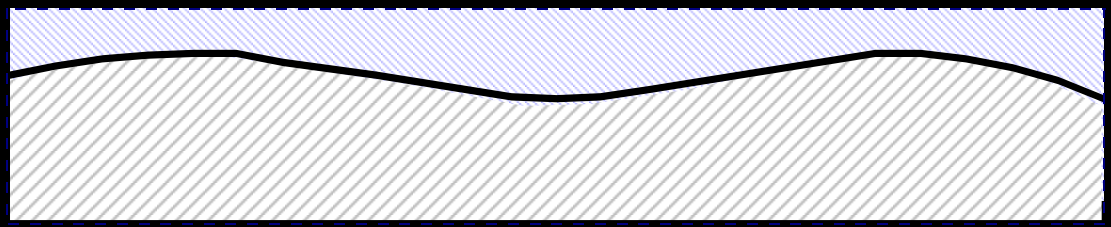
- Different explosive cladding methods:
  - Open air cladding
  - Vacuum cladding

Why explosive cladding in vacuum?

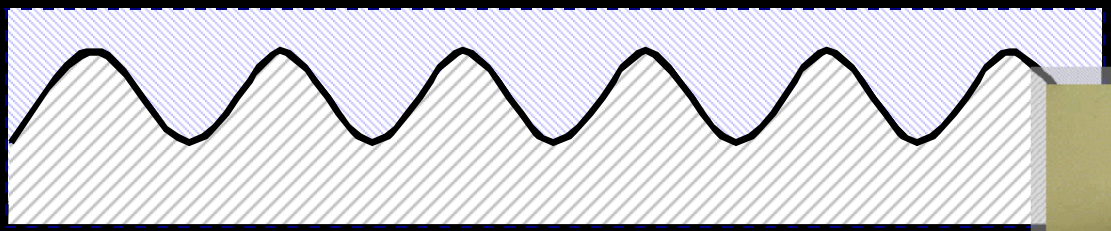


- Vacuum cladding
  - Cladding in a vacuum chamber
  - Under pressure: 50 mBar
  - Noise level: 70 dB(A)
  - Environmental friendly
  - No air in the stand-off space during welding
  - No turbulence in the interface
  - Optimal process control such as:
    - Detonation velocity, vacuum condition, temperature, moisture, stand-off space, etc.

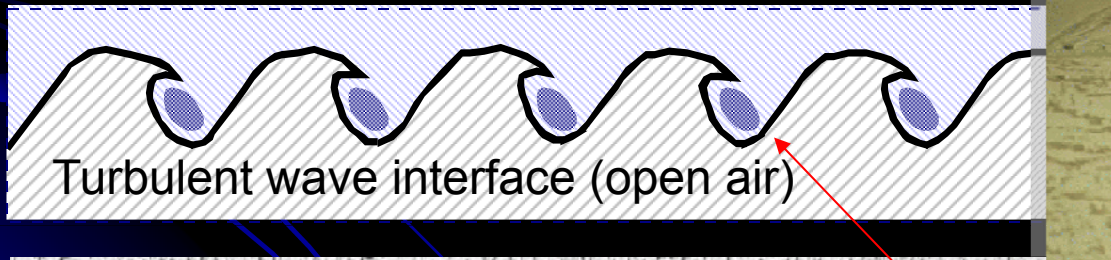
Three different interfaces



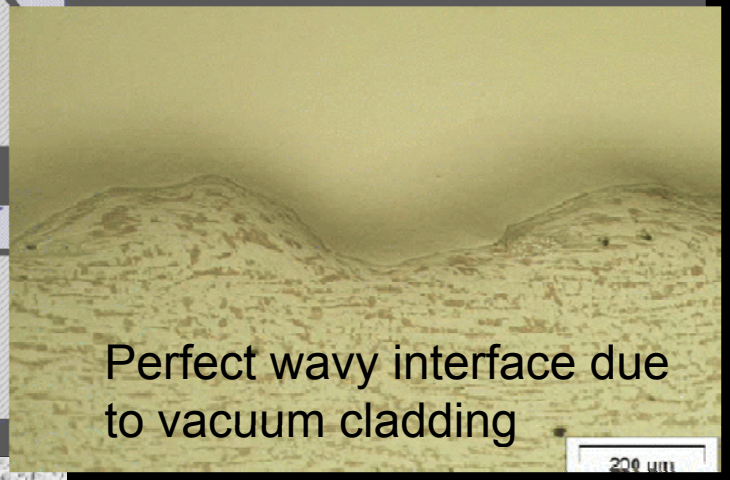
Smooth wave interface



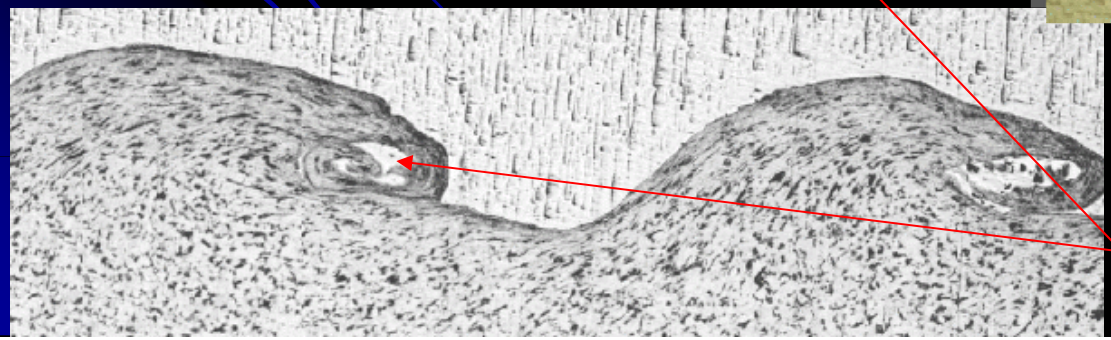
Undulating wave interface



Turbulent wave interface (open air)



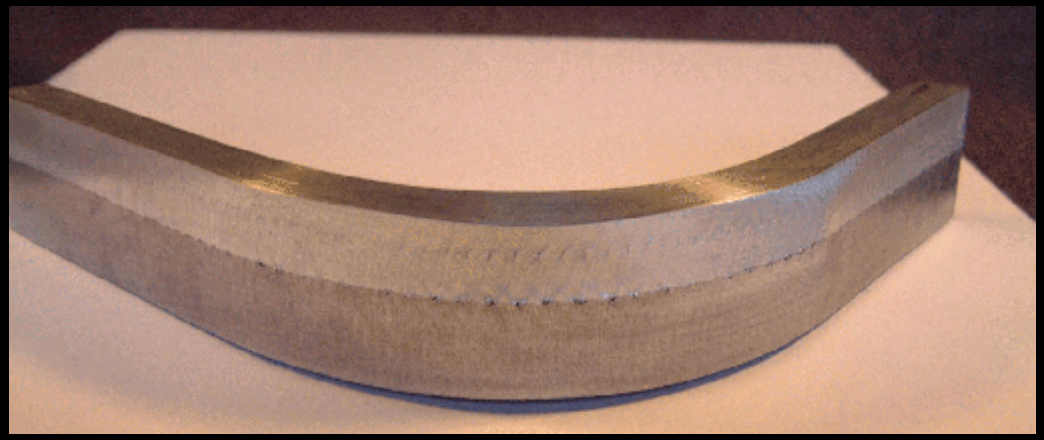
Perfect wavy interface due to vacuum cladding

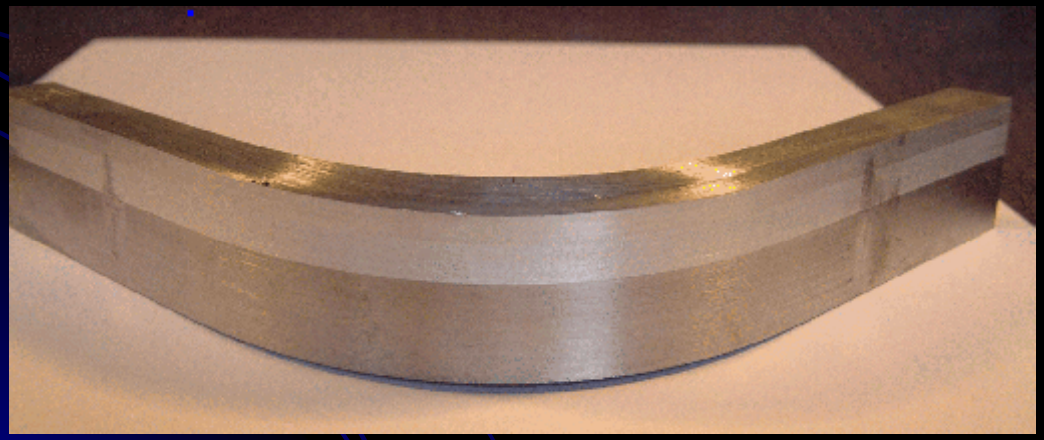


Oxides caused by washing of waves (open air)

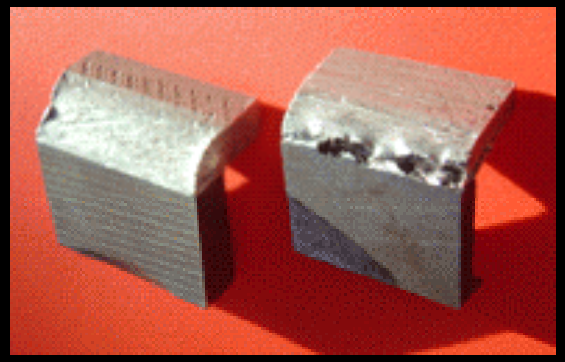
Side bend and hammer bend test

Side Bend Test 90°



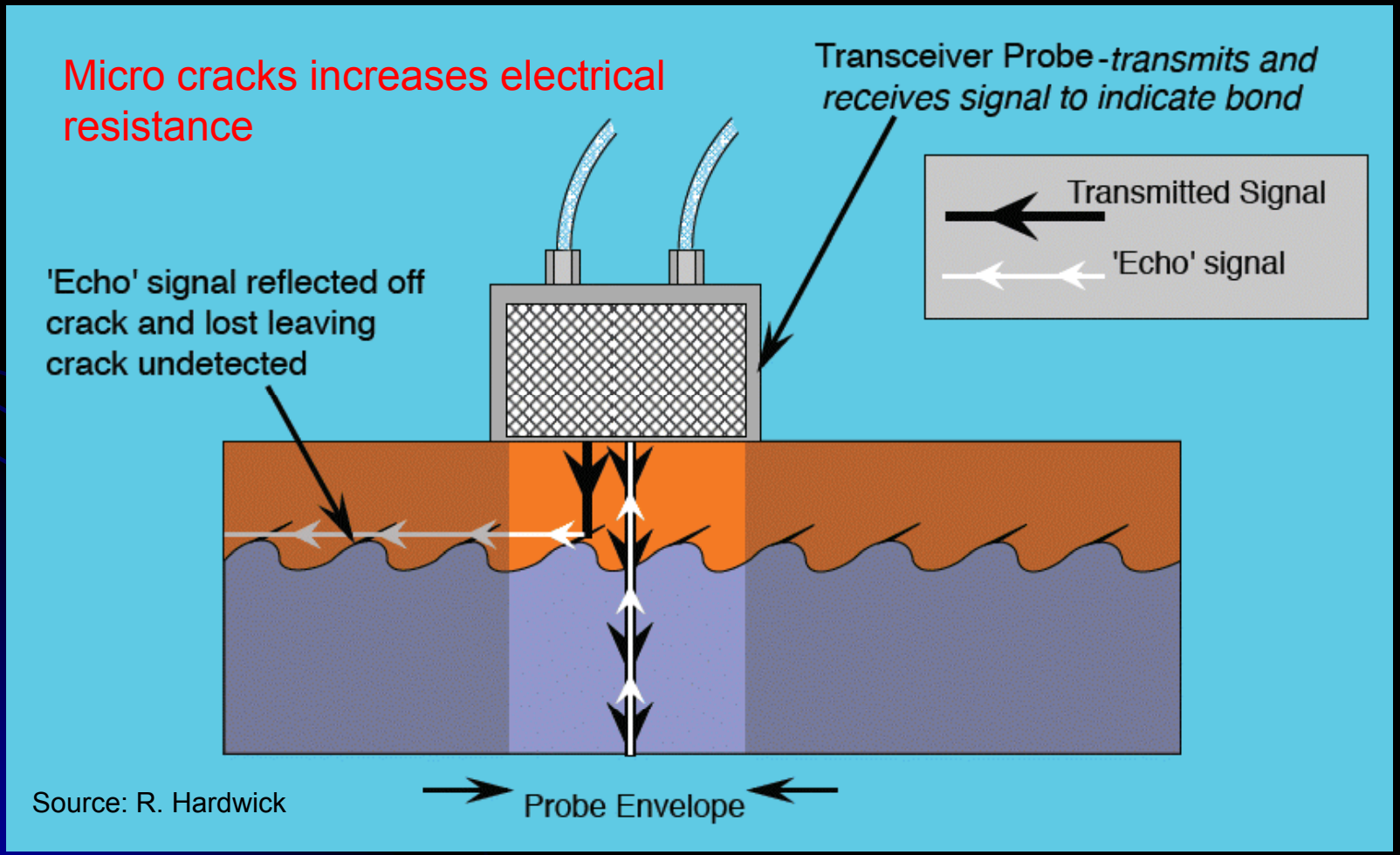


Top: Atmospheric cladded
Bottom: Vacuum cladded Triplate

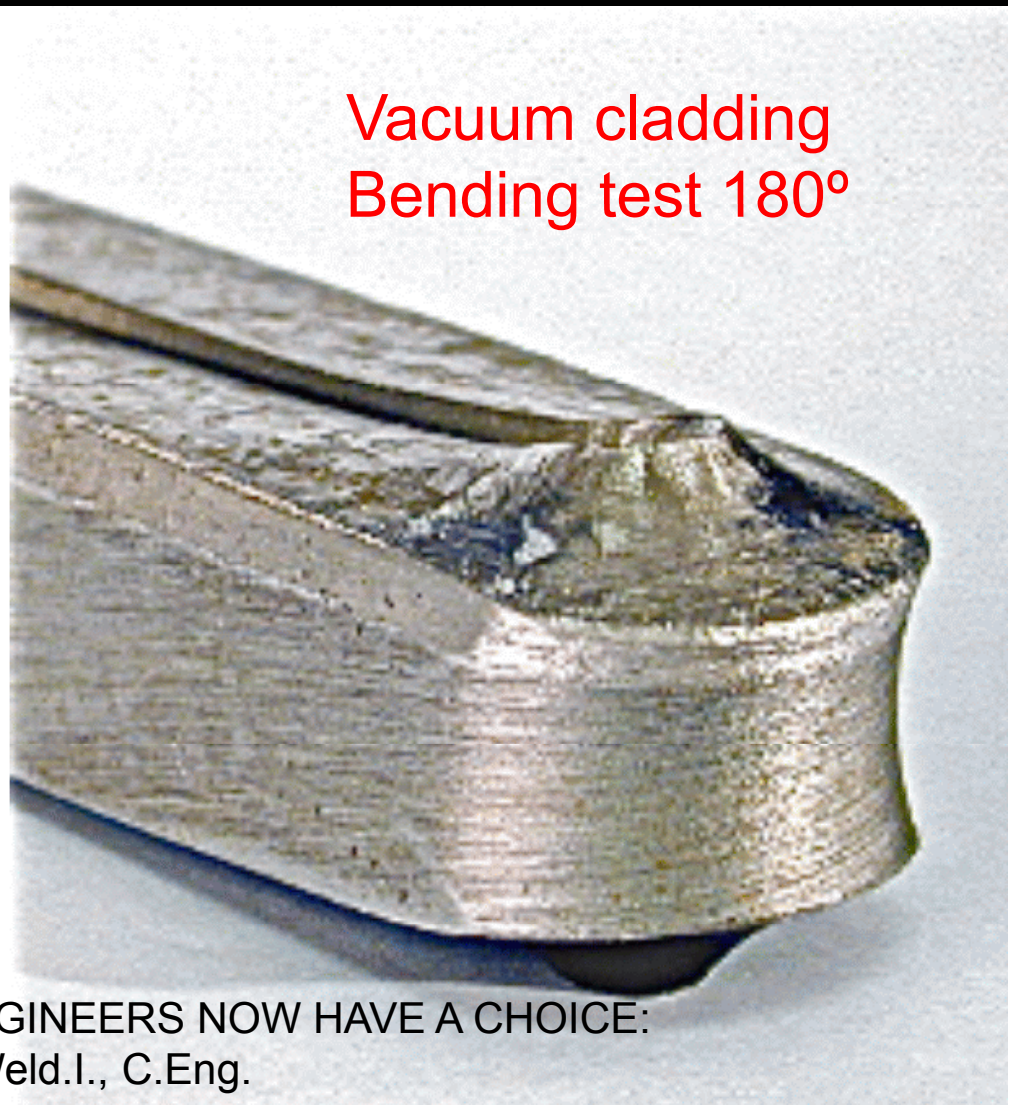


Micro shear cracks caused by high waves

- Special when the clad metal is less ductile
- Neglect risk by using vacuum technology



Atmospheric versus vacuum



THE EXPLOSIVE BONDED INTERFACE. ENGINEERS NOW HAVE A CHOICE: WAVES OR NO WAVES - By R. Hardwick F.Weld.I., C.Eng.

Summary of differences

Open air cladding	**Vacuum cladding**
Oxides with porosity	100% dense
Oxides initiate fractures	Does not apply
Holes initiate corrosion	Does not apply
Stress relief treatment due to cold working	Not necessary since cold working is limited
Variable weather conditions	Does not apply since it is inside
Harder to machine (sawing and bending)	Easy sawing and forming thanks to high ductility

Technical support

- SMT is supporting their customers in order to achieve an optimal operation condition
- An important issue is the welding procedure and recommendations
- And of course the *do's* and the *dont's*
- Moreover we are grinding the contact surfaces to reduce the resistance after welding to the anode and steel bracket

The vacuum chamber

Entrance of the vacuum chamber

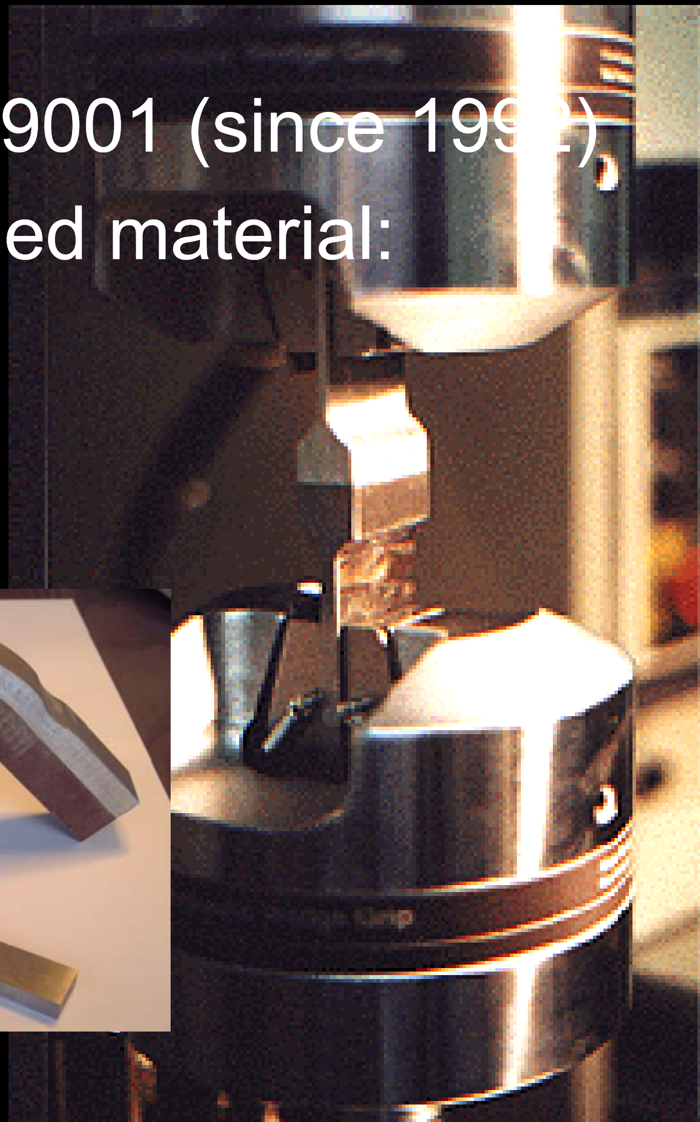
Cladding set-up just before the explosion welding process

The vacuum chamber

- Advanced vacuum pumps

Quality control

- Procedures according to ISO 9001 (since 1992)
- Testing of the explosive cladded material:
  - Ultrasonic Testing
  - Destructive testing:
    - Tensile test
    - Bend tests
    - Shear test
    - Impact tests
    - Fatigue test



Quality control

- Independent inspection authorities such as Lloyd's, TUV, GL, DNV, ABS, Bureau Veritas
- Certificates according to EN 10204 3.1. or 3.2

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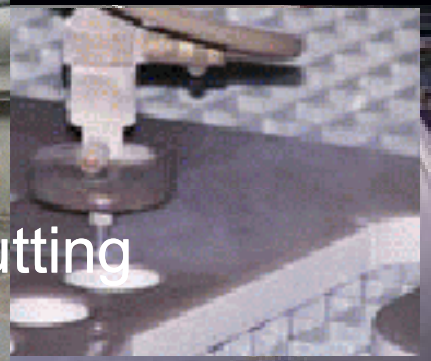
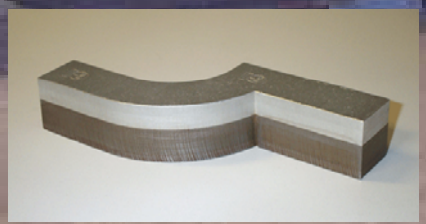
Processing the explosive clad material

- Processing of the explosive cladmaterial:
  - Welding
  - Machining
  - Plasmacutting, lasercutting, waterjet cutting
  - Bending pressing to vessel heads
  - Rolling to cilinders for shells
  - Heat treatment





Conclusions

- High tech material
- No bad influence on the environment
- Saves costs
- Research for new applications: new metal-combinations
- Increasing of possibilities
  - sizes of the clad plates and production capacity

Thank you very much for your attention