



WEBINAR

Cable Manufacturing 101

October 26, 2022

By: Wissam Geahchan, Applications Engineer

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ELECTRIFY THE FUTURE

ATTENTION

AUDIENCE PARTICIPATION

- **Questions can be asked at any time using the chat function on the webinar screen**
- **Any unanswered questions will be followed up through email**
- **This presentation, a recording of the webinar and a brief survey will be emailed to all registrants**

Wissam Geahchan



Applications Engineer, Nexans Canada

- Active member on several industry standards committees
- Experience applying the Canadian Electrical Code in a variety of applications
- Licensed soccer coach

Agenda

- Introduction
- A Brief History
- Manufacturing Process
 - Materials
 - Metallurgy and Compounds
 - Process
 - Drawing
 - Stranding
 - Extrusion
 - Cabling
 - Finishing
 - Testing and Quality Assurance
- Nexans Products
- Key Takeaways
- Q&A



Nexans Canada is proud to be a cable manufacturer for over 110 years!

1911  **canada[®]
wire**
Started with Canada Wire in Toronto, ON



3 Manufacturing Plants



Copper Rod Mill
Montreal, QC



**Residential,
Commercial &
Industrial**
Fergus, ON



**Utility -
Distribution &
Transmission**
Weyburn, SK

Our Purpose:

**ELECTRIFY
THE FUTURE**

Our past, present and future
converge to electrification



Introduction

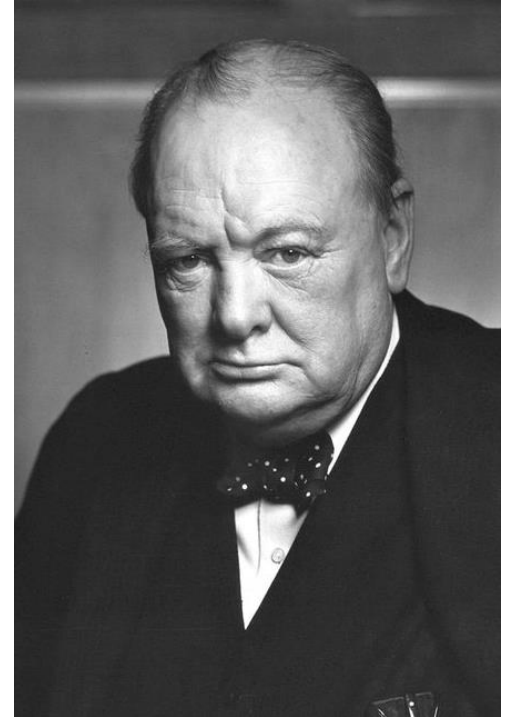
- Raw Material → Finished Cable
- Materials matter!
- The processes and materials that we will describe here are common in all wire and cable plants.



A Brief History (1)

[Learn all you can about the history of the past, for how else can one even guess what is going to happen in the future.]

Winston Churchill



A Brief History (2)

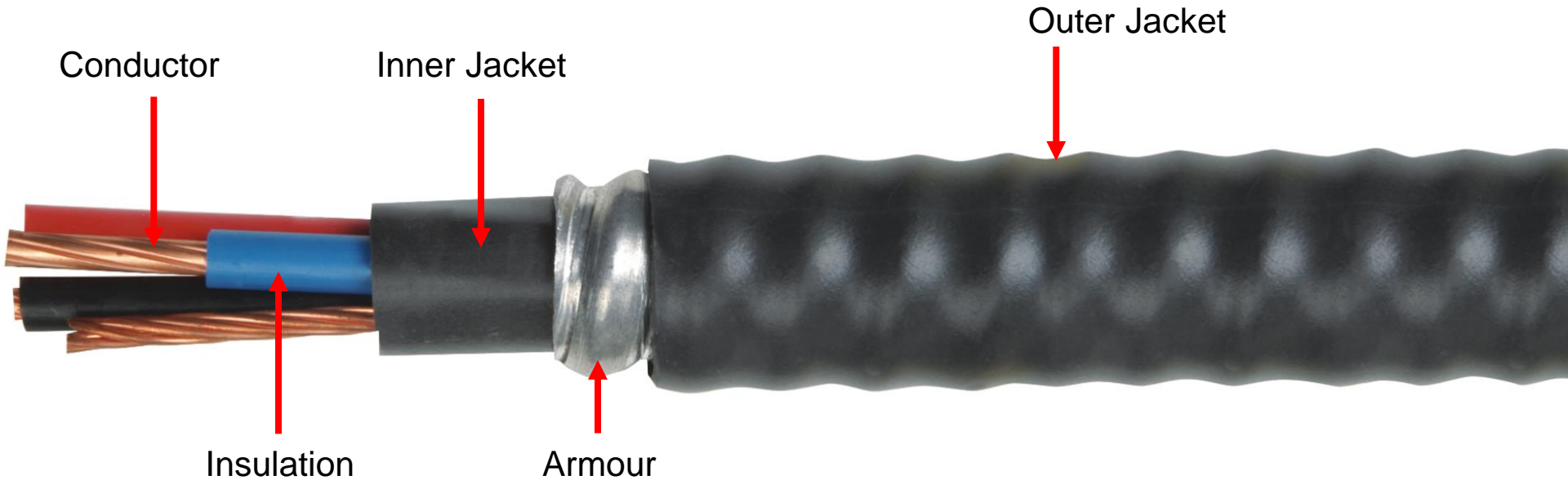
Wire and cable have been used for over 200 years dating back to the early 1800s when electricity began to be studied.

Humphry Davy, Hans Christian Oersted, George Simon Ohm, Joseph Henry, Michael Faraday, Thomas Edison, to name a few.

**1844 – Charles Goodyear Patent
Vulcanized natural rubber
telegraph cable**



Main Cable Components - A Refresh*



*Refer to our “Cables 101” webinar, available on our website, if you are interested in learning more.

Manufacturing Processes

Metallurgy

Compounds

Drawing

Stranding

Extrusion

Cabling

Finishing

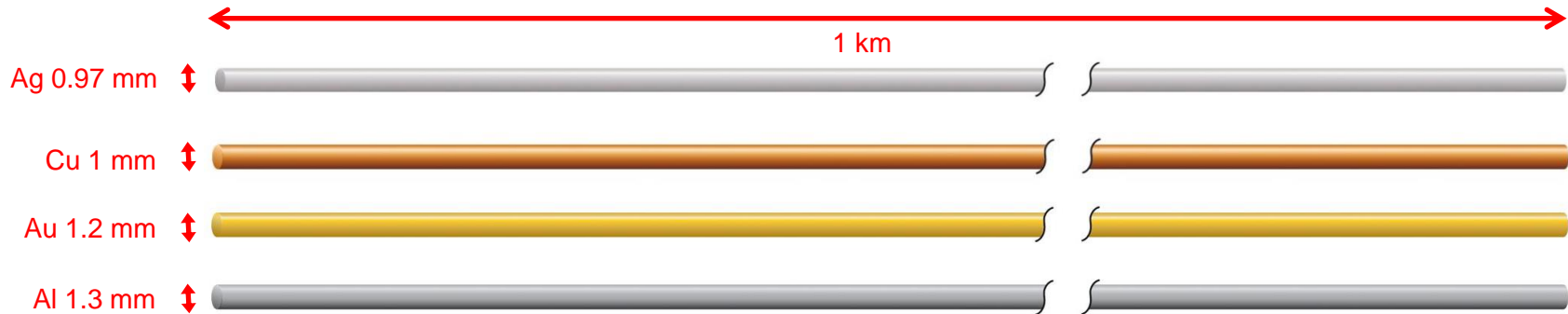
“Pre-processes”

Processes

Metallurgy

Conductor material selection

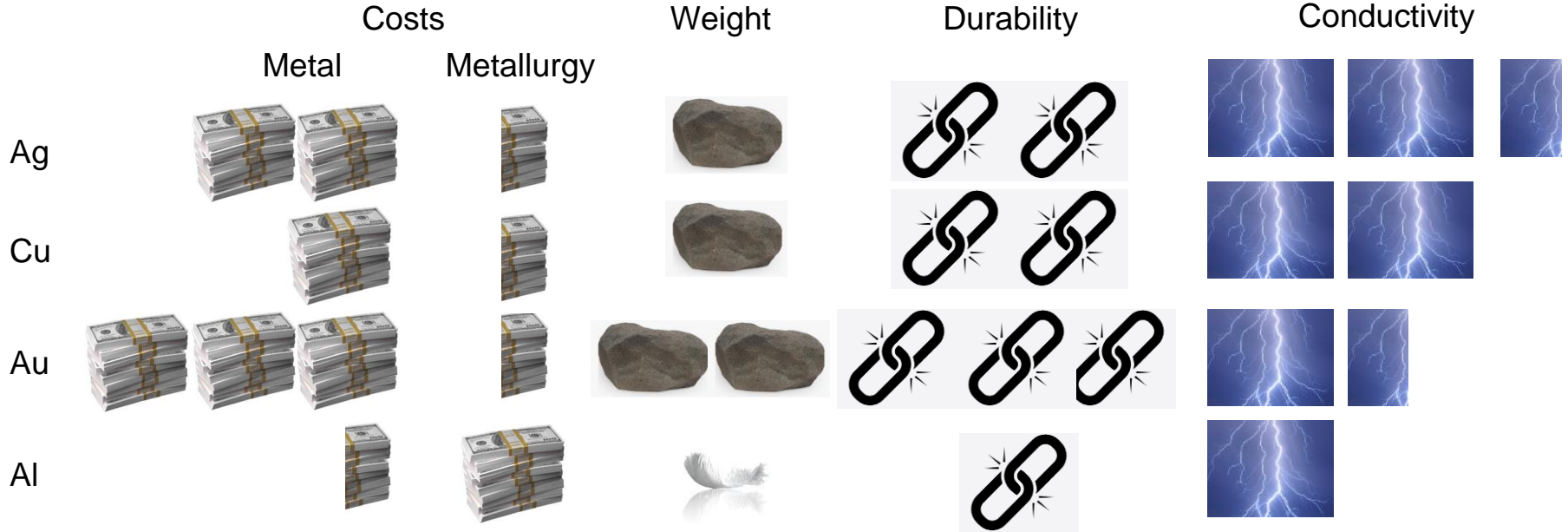
Below is a comparison of the 4 best conductors of electricity.



Advantages and disadvantages also include price, weight, and processing.

Metallurgy (2)

More Comparisons



Metallurgy

Compounds

Drawing

Stranding

Extrusion

Cabling

Finishing

Metallurgy (3)

From CATHODE to ROD

- The raw materials for conductors are electro-refined cathodes of ultrapure metals. Resistivity increases with the impurity content.
- From CATHODE to ROD in Rod Mills or Continuous Casting Units.



Compounding

Compounding is the operation where different raw materials like polymers, fillers and additives are mixed to manufacture the granules which will be used as a raw material in the production of cables (... or compounds).

Additives: a few %
Fillers: up to 60 %



Metallurgy

Compounds

Drawing

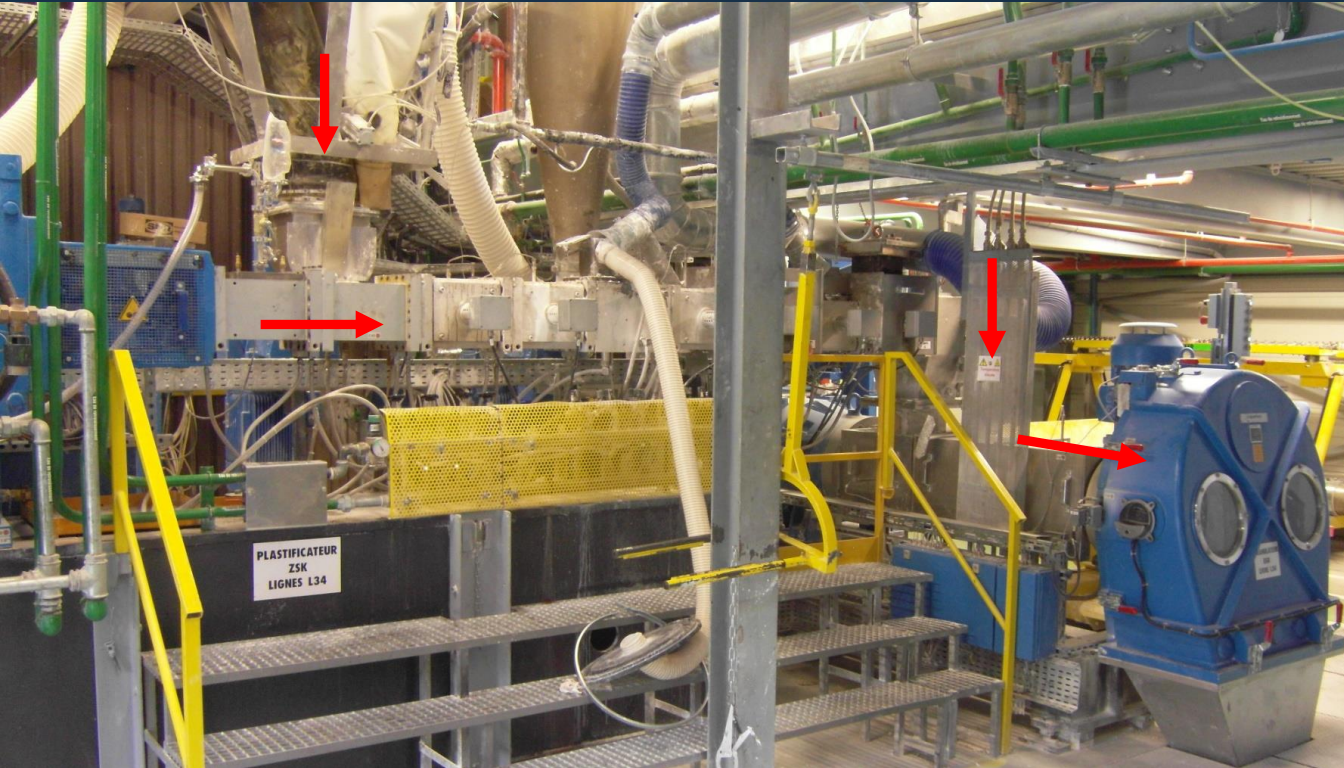
Stranding

Extrusion

Cabling

Finishing

Compounding (2)



Metallurgy

Compounds

Drawing

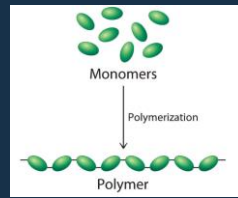
Stranding

Extrusion

Cabling

Finishing

Polymer Compounds (1)



Polymer Compounds are materials composed of repeating chains of molecules and can have varying properties.

Required for insulation and protection from both mechanical abuse and electrical stress.

Can be received ready-for-use OR produced in-house.

Masterbatching is the addition and mixing of ingredients on the extrusion line with the aim to improve flexibility, lifetime, flame spread behavior, costs, etc.

Honourable mentions:

Air is the cheapest insulating material.

Paper insulation is still in use after more than 100 years but has two drawbacks...

- Very poor insulator when wet.
- Many paper layers needed, which makes the process slow and expensive.



Metallurgy

Compounds

Drawing

Stranding

Extrusion

Cabling

Finishing

Polymer Compounds (2)

The four types of materials are:

1. **Polyethylene** – Electrical properties
2. **PVC** – Limited Flame Spread Properties
3. **Elastomers (Rubbers)** – Flexibility
4. **Other Polymers** – For different properties

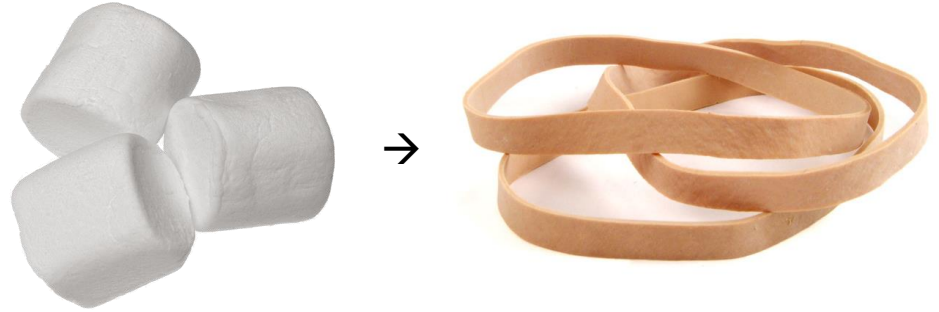


Polymer Compounds (3)

Crosslinking is an operation which allows us to modify the properties of materials.

Not all materials can be crosslinked.

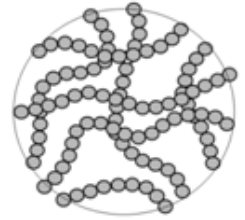
The best-known example is **vulcanization** of rubber, invented by Charles Goodyear in 1839 and patented in 1844.



Polymer Compounds (4)

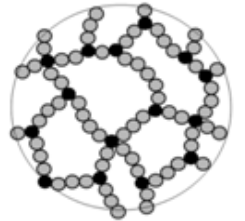
Thermoplastic material (not crosslinked)

The polymers are made of a chain of molecules which can slide with respect to each other. Relatively soft, softens at a relatively low temperature (90C).



Thermosetting material (crosslinked)

After crosslinking, the polymer can no longer be melt-processed, making it a thermosetting material.



Polymer Compounds (5)

PE



XLPE



Metallurgy

Compounds

Drawing

Stranding

Extrusion

Cabling

Finishing

Other Materials

Paper

Insulation paper or filling paper - craft paper

Wires, Strings and Yarns

Identification string, binding string, water swellable yarns, jacket opening string, reinforcement/protection yarns, or steel wires for armoring

Filling compounds

Grease, special compounds for certain performance, chalk to avoid wire sticking with the jacket, tar for submarine cables, swellable powder.



Other Materials

Metallurgy

Compounds

Drawing

Stranding

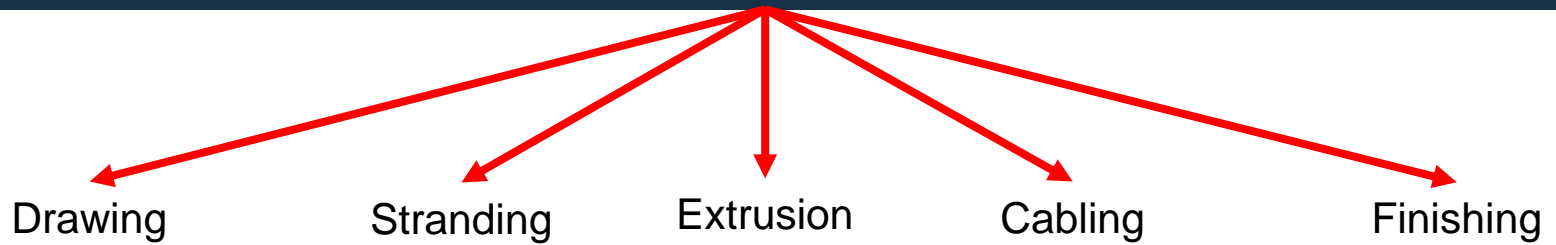
Extrusion

Cabling

Finishing

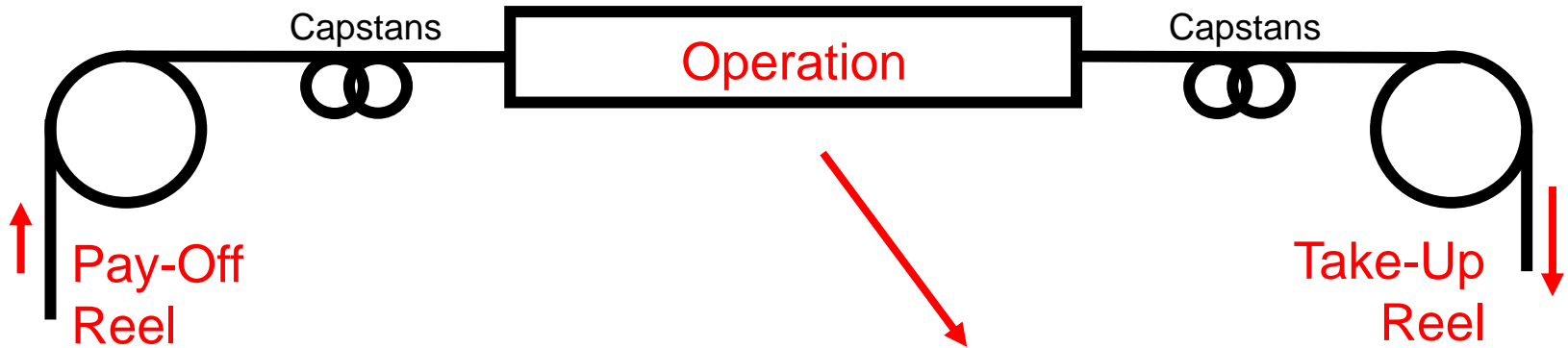

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Processes



Overview

The basic set up is as follows:



Metallurgy

Compounds

Drawing

Stranding

Extrusion

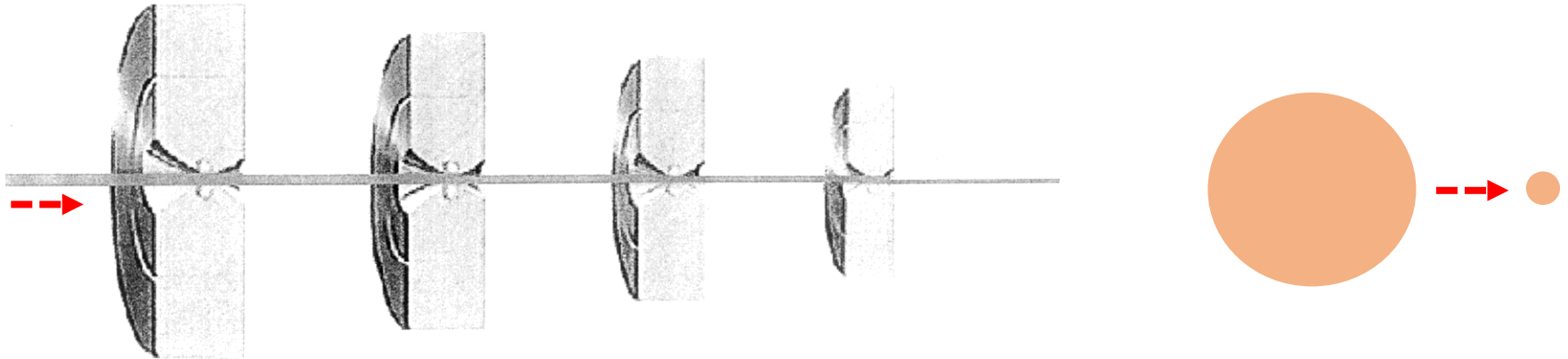
Cabling

Finishing

Drawing (1)

Drawing is the plastic deformation of a metal wire by pulling it thru calibrated dies, of even smaller diameter.

- Copper rod is commonly 5/16" (8mm) diameter
- Aluminum rod is commonly 3/8" (10mm) diameter
- Larger rod may be used when making solid conductors with a diameter larger or only slightly smaller than the common rod size.



Metallurgy

Compounds

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Extrusion

Cabling

Finishing

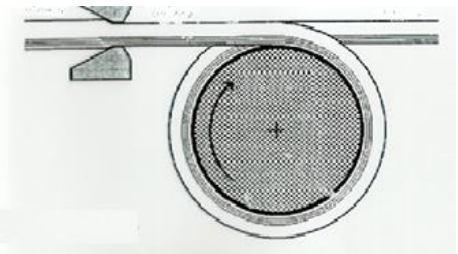
Drawing (2)

Results of wire drawing...

- Wire drawing increases the metal hardness and reduces conductivity.
- Proper selection of the rod may allow for drawing to temper.
- If this is not possible, **annealing** may be required.



Drawing: cold deformation



Metallurgy

Compounds

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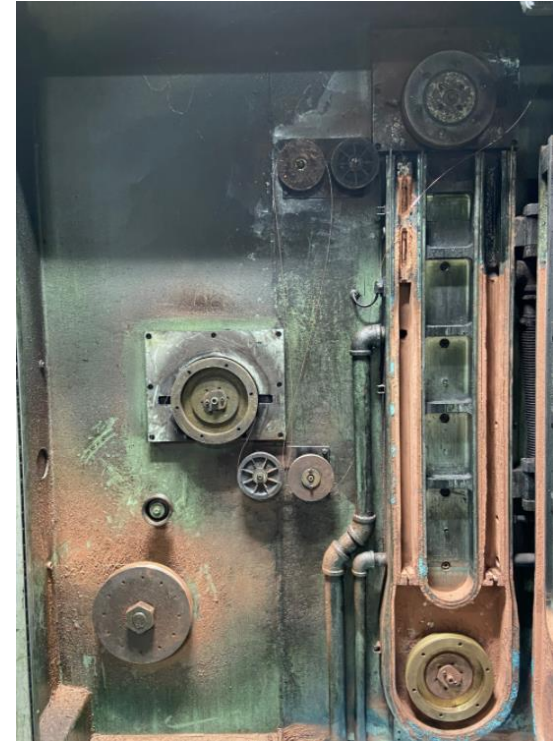
Annealing

Annealing is a heat treatment that alters the physical and mechanical properties of a material to increase its ductility and reduce its hardness (making it more workable)

Softens the metal temper and raises the conductivity.

The product returns its flexibility + elongation properties.

Annealing can be done in batch ovens or in-line heating “on the fly” for small conductors.



Metallurgy

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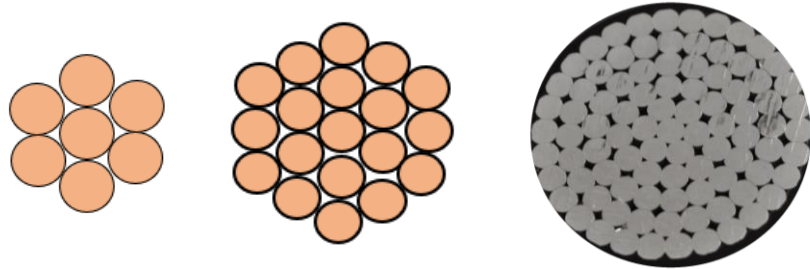
Stranding

Stranding is the application of subsequent layers of individual strands of wire around a center point.

Conductors are stranded to provide flexibility.

Each layer has 6 or more wires than the layer below it. This forms an almost natural construction:

- 1 wire = solid
- 7 wire = 1 center wire plus 6 around it
- 19 wire = 1 + 6 + 12
- 37 wire = 1 + 6 + 12 + 18



Strand Terminology

- Diameter, Lay length, Compression, Compaction, Unilay, Concentric, Bunching, Strand fill...

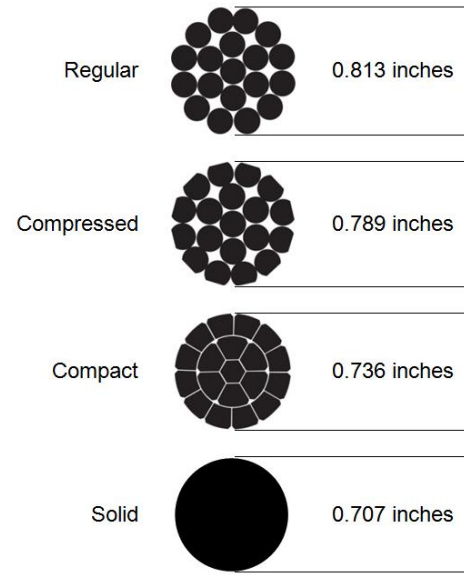
Stranding (2)

Compression – the reduction of the diameter of the finished strand by approximately 3%.

Compaction – the reduction of the diameter of the finished strand by approximately 8%.

Done by pulling through calibrated dies.

Purpose is to reduce the strand size slightly, which means we use less insulation at extrusion and makes the strand a little stronger for the extrusion process.



500 kcmil Conductor

Reduces Diameter
But
Reduces Flexibility

Stranding (3)

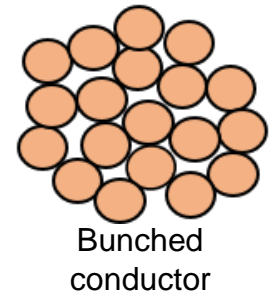
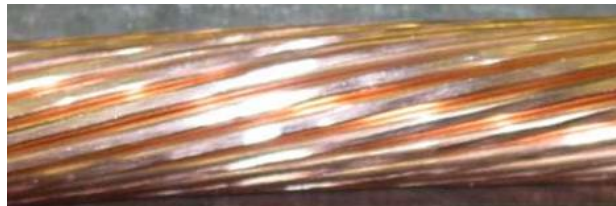
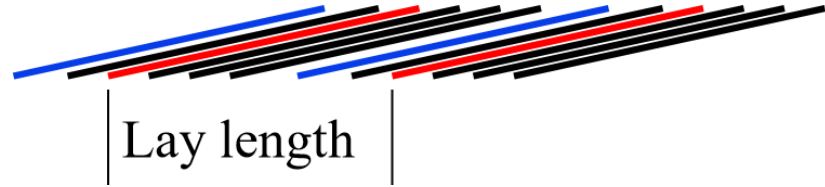
Lay-length – The measured distance, along the strand, between each twist.

Unilay – Each layer is twisted in the same direction with the same finished lay length.

Concentric Lay – Each layer is twisted in opposite directions with longer lay lengths on subsequent layer.

Bunching (like stranding) – Strands are twisted together without control over the final strand location.

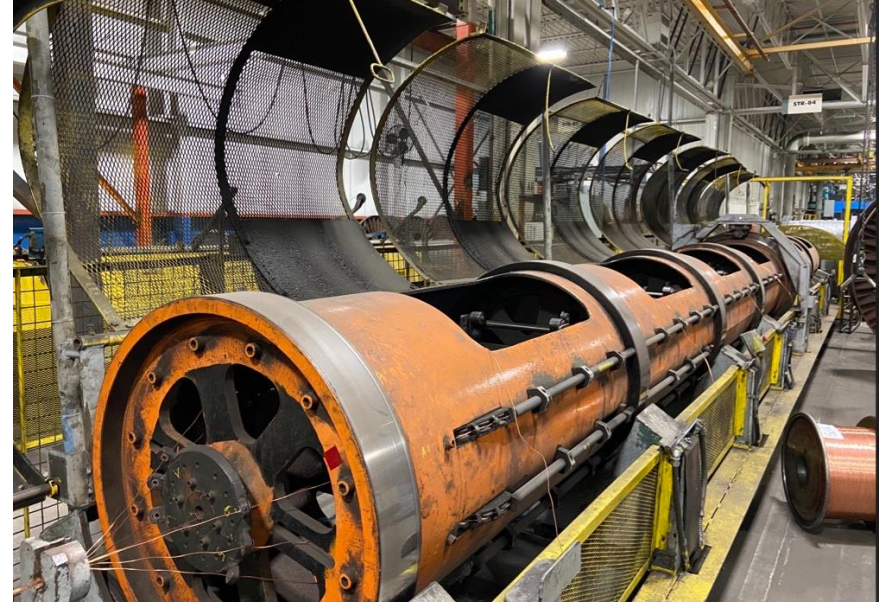
Strand Fillers – May be added where wires are brought together during stranding.



Stranding (4)

Tubular stranders are common for making 7 and 19-strand conductors.

- Bobbins (small reels) are placed inside a long tube that rotates, laying wires along side each other.



Metallurgy

Compounds

Drawing

Stranding

Extrusion

Cabling

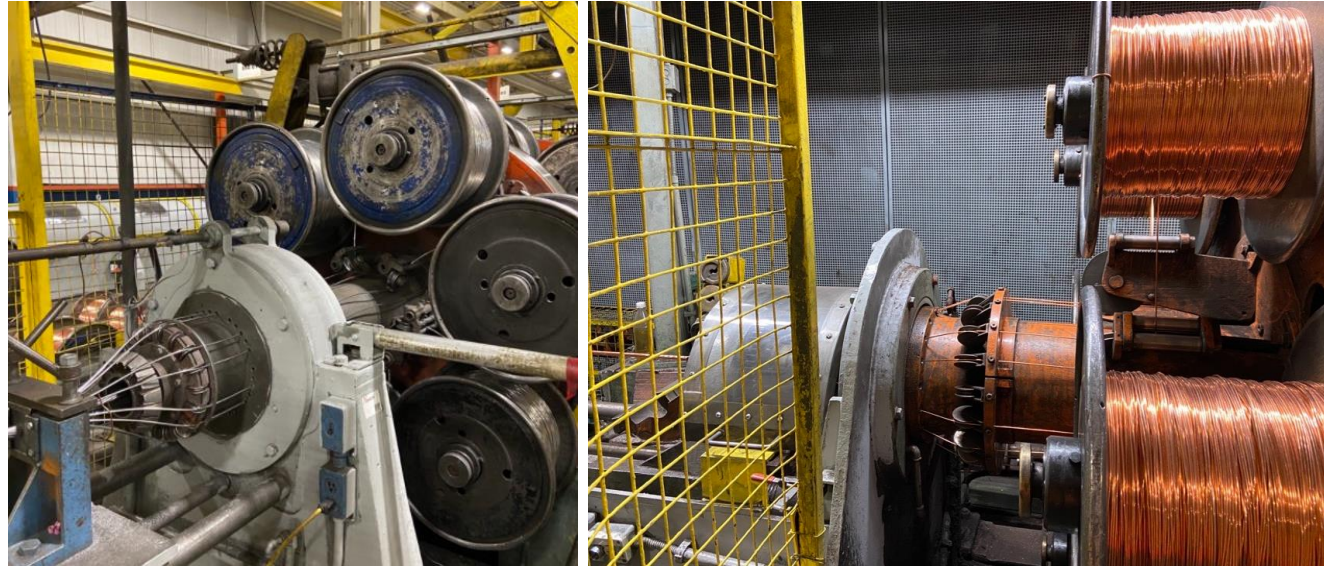
Finishing

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Stranding (5)

Conductors with more strands are often made on **rigid-frame (or planetary)** stranders.

- Process where the reels are put on a “cage” and rotated around the center core to lay the individual wires on to the strand.



Metallurgy

Compounds

Drawing

Stranding

Extrusion

Cabling

Finishing

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Stranding (6)

Two other common types of stranders are a **single twist** or **double twist strander**.

Single twist strander – refers to the process where a flyer arm is used to twist the conductors and then lay them on a reel

Double twist strander – like a single twist except that the flyer arm provides 2 twists for each revolution.



Double-twist strander

Extrusion

Extrusion is the operation which puts material around the conductor or the cable core.



Metallurgy

Compounds

Drawing

Stranding

Extrusion

Cabling

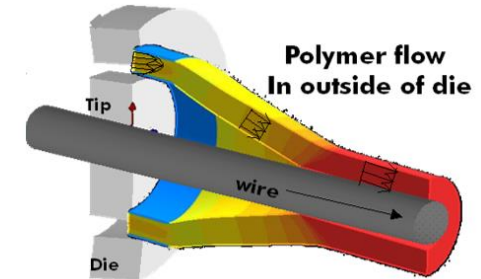
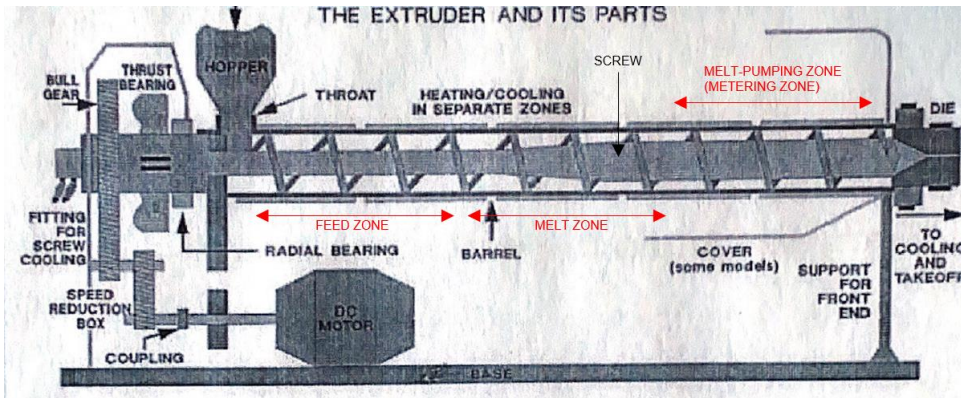
Finishing

Extrusion (2)

Conductor and compound meet at the extruder.

The basic principles of extrusion are unaffected by the material extruded.

Below is a diagram showing the basic single-screw extruder and its elementary components.

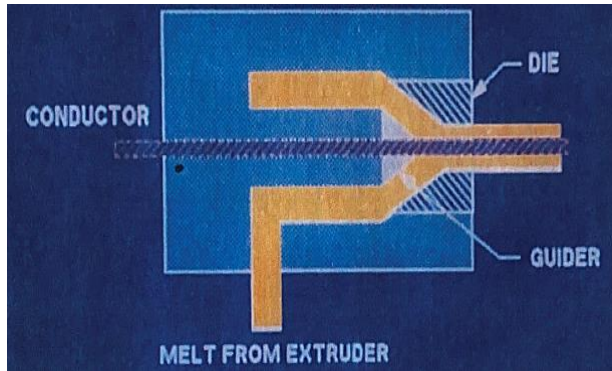


Extrusion Heads (3)

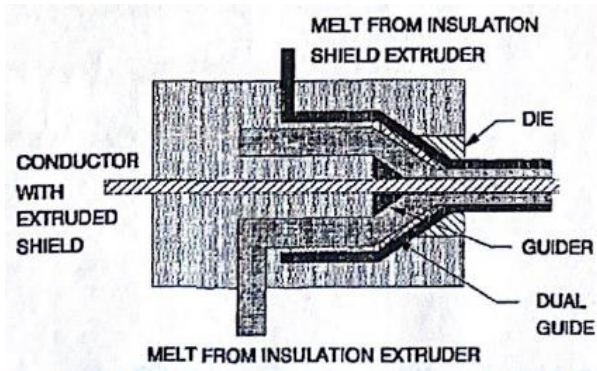
Melt from the extruder metering section flows through a head and is deposited on whatever is passing through the head.

Dual and triple heads provide parallel path flow in the head with each “outer layer” being deposited over the inner layer.

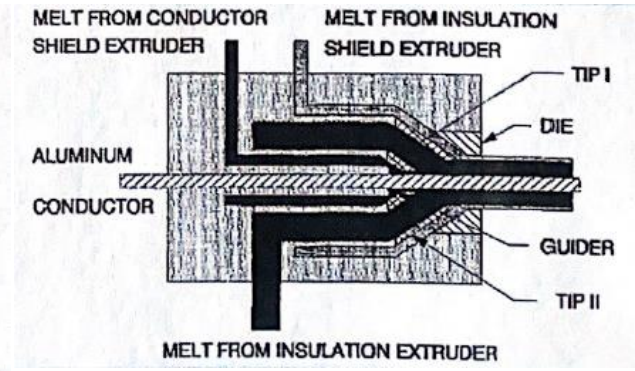
Single Head Extruder



Dual Style Head



Triple Style Head



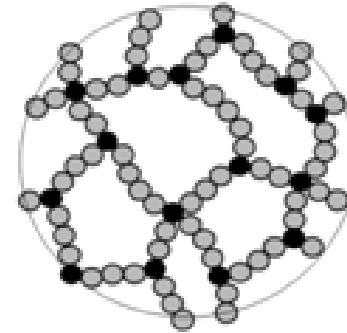
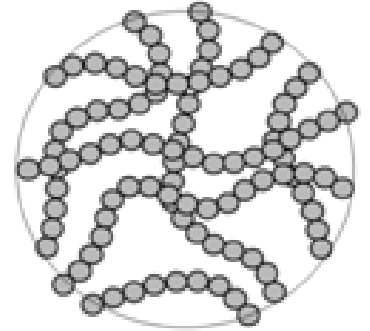
Extrusion (4)

Crosslinking

The best-known method of crosslinking is **vulcanization**...

Other methods include **irradiation** and **silane**.

Note - The method used depends on the equipment available in the plants and on the performance expected.



Metallurgy

Compounds

Drawing

Stranding

Extrusion

Cabling

Finishing

Extrusion (5)

In **Vulcanization**, peroxide is added to the polymer to break the chemical bonds.

Even stronger bonds re-assemble between the polymer chains while the polymer is “cooked” at a given temperature and for a given time as it goes through a continuous vulcanization (CV) line.



Metallurgy

Compounds

Drawing

Stranding

Extrusion

Cabling

Finishing

Extrusion (6)

When the cable insulation gets very large, gravity may deform the insulation before crosslinking, which means the cable would no longer be perfectly round.

One way to overcome this is to use a **Vertical CV** line rather than a catenary.

To the right is a highly simplified view of the installation.



Metallurgy

Compounds

Drawing

Stranding

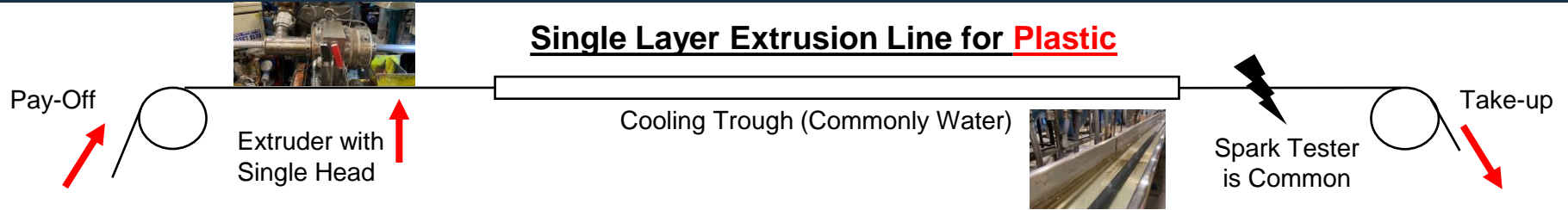
Extrusion

Cabling

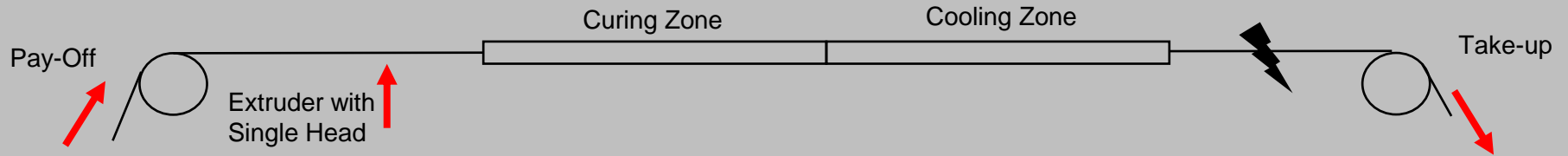
Finishing

Extrusion – Common Lines (7)

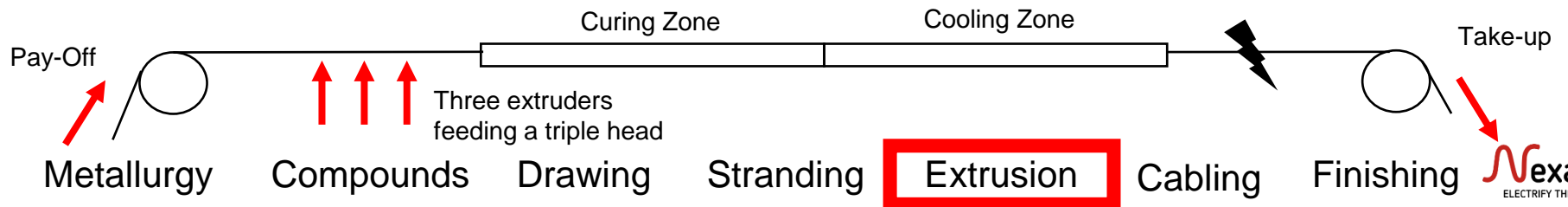
Single Layer Extrusion Line for **Plastic**



Single Layer Extrusion Line for **Continuous Vulcanization**



True-Triple-Extrusion Line for **Continuous Vulcanization**



Cabling (1)

Once the basic components of the cable are prepared, we assemble the cable in what is called the **Cabling** step.



Metallurgy

Compounds

Drawing

Stranding

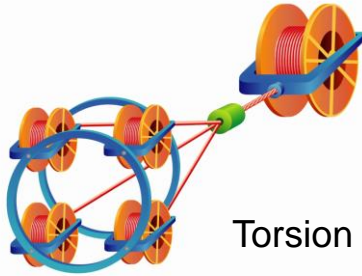
Extrusion

Cabling

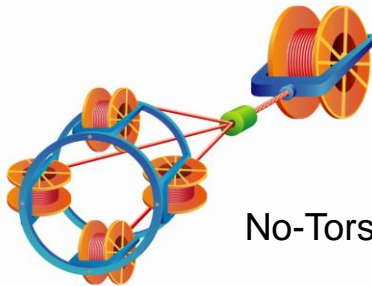
Finishing

Cabling (2)

Two main methods:



Torsion



No-Torsion

Rotating pay-off, Fixed take-up



Fixed pay-off, Rotating take-up



Metallurgy

Compounds

Drawing

Stranding

Extrusion

Cabling

Finishing

Finishing

Some **Finishing** operations include adding:



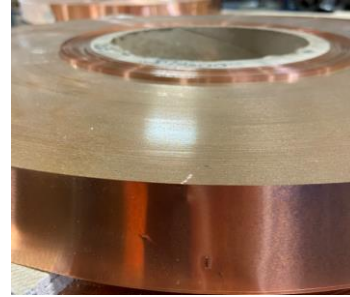
Metallic and/or fabric braid



Corrugated or
folded metal tape



Concentric wires or metallic tape



A sheath
and/or
armour

Testing & Quality Assurance (QA) (1)

The different types of testing include:

1. Design qualification tests
2. Material tests
3. In-process tests
4. Finished product tests



Testing & QA (2)

Design Qualification Tests:

To ensure a cable is suitable for production

- Electrical/Physical measurements
- Load cycling
- Deformation and Strippability tests
- and others...

Incoming Material Tests:

To produce in-house materials, input materials are subjected to appropriate published and unpublished tests.

In-process Tests:

At every stage of manufacturing, tests are done frequently to avoid the generation of scrap material.

Finished Product Tests:

To ensure final product is compliant

- AC or DC spark tests
- Optional insulation resistance tests
- Conductor resistance tests
- And others...

Nexans Canada Products

Residential

- Bare Copper
- CANADEX® NMD90
- HEATEX® NMD90
- SUPERVEX® NMWU

Commercial

- AC90
- AC90 ISO-BX
- INSTAGLIDE® RW90 & RWU90
- INSTAGLIDE® T90 Nylon
- TWU

Industrial

- DriveRx® VFD
- FIREX® TECK90 – 600 V & 1 kV

Utility

- Bare ACSR & AACSR
- Bare Aluminum & Al Alloy
- Covered Overhead Distribution Line Wire
- ENERGEX® CN & SP Medium Voltage
- NS75 & NS90
- USEI75 & USEI90 & USEB90

Bare Copper



Process:

1. Drawing
2. Stranding

Applications:

Suitable for bonding and grounding electrical circuits and systems

ASC & ACSR



Process:

1. Drawing
2. Stranding
3. Extra - strand filling

Applications:

Suitable for overhead installations

INSTAGLIDE® RW90, RWU90 & T90



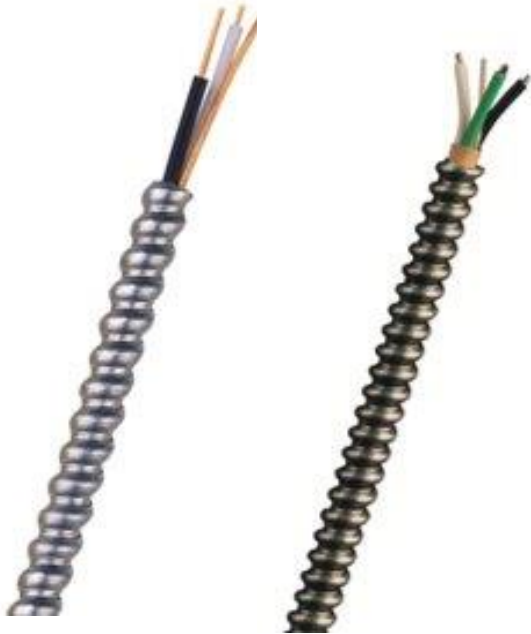
Process:

1. Drawing
2. Stranding
3. Extrusion

Applications:

For open wiring and raceways in dry or wet locations.

AC90 & AC90 ISO-BX



Process:

1. Drawing
2. Stranding
3. Extrusion
4. Cabling / Assembling
5. Armouring

Applications:

Armoured cable for commercial, industrial, and apartment use.

CANADEX® NMD90 & SUPERVEX® NMWU



Process:

1. Drawing
2. Stranding (or not, for solid wires)
3. Extrusion – 1st pass
4. Extrusion – 2nd pass

Applications:

Non-metallic sheathed cable for residential applications including lights, outlets, kitchens, washing machines, etc.

FIREX[®]

TECK90

1 kV & 600V



Process:

1. Drawing / Stranding / Extrusion
2. Cabling
3. Extrusion 1st pass (inner jacket)
4. Armouring
5. Extrusion 2nd pass (outer jacket)

Applications:

Service entrance (above / below ground), apartment buildings, commercial complexes, etc. Dry / Wet. Open wiring, cable trays, direct burial. All hazardous locations.

DriveRx[®]

VFD



Process:

1. Drawing / Stranding / Extrusion
2. Cabling
3. Armouring
4. Extrusion 2nd pass (outer jacket)

Applications:

Recommended for connections from VFD to motor. Industrial, commercial, and utility installations. All hazardous locations.

ENERGEX® Medium Voltage

Concentric Neutral (CN)



Process:

1. Drawing
2. Stranding
3. Extrusion (CV)
4. Metallic shield application (as concentric wires)
5. Extrusion (jacket)

Applications:

Predominantly used for three-phase primary underground distribution 5-46 kV. Can be direct buried, buried in ducts, and/or exposed to sunlight.

Process:

1. Drawing
2. Stranding
3. Extrusion (CV)
4. Metallic shield application (as helically applied tape or longitudinally applied corrugated tape)
5. Extrusion (jacket)

Applications:

Predominantly used for three-phase primary underground distribution 5-46 kV. Can be direct buried, buried in ducts, and/or exposed to sunlight.

Shielded Power (SP)



USEI75 USEI90



USEB90



NS75 & NS90



Process:

1. Drawing
2. Stranding
3. Extrusion (1st pass)
4. Extrusion (2nd pass)
5. Cabling

1. Drawing
2. Stranding
3. Extrusion (1st pass)
4. Metallic shield application (conc wires)
5. Extrusion (2nd pass)

1. Drawing
2. Stranding
3. Extrusion (1st pass)
4. Extrusion (2nd pass)
5. Cabling

Applications:

Underground Service Entrance cable with an Insulated ground conductor.

Underground Service Entrance cable + Bare ground conductor(s).

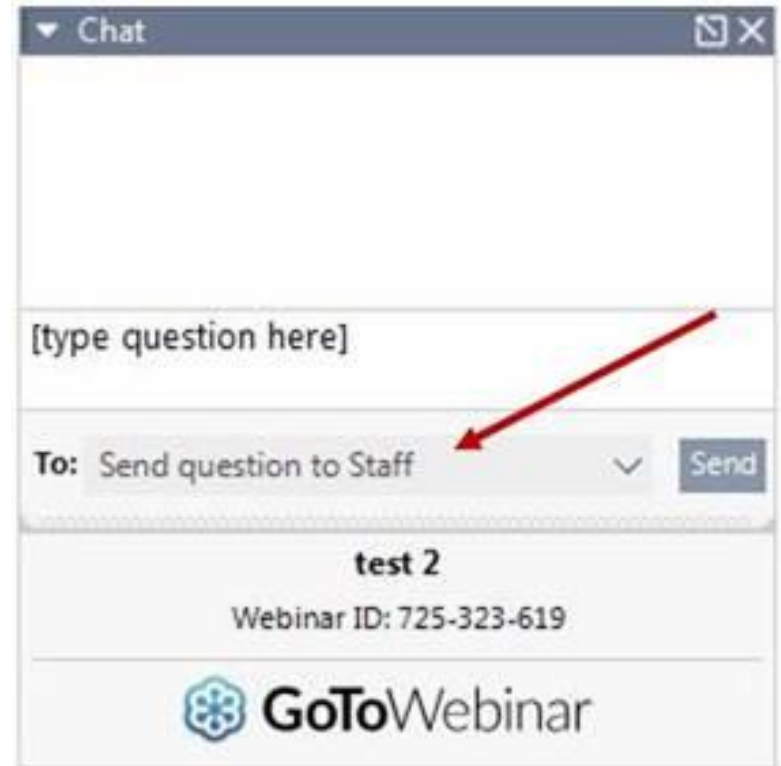
Neutral Supported overhead service entrance cable for overhead applications.

Key Takeaways

- Presented the **pre-processes** and **processes** involved in wire & cable manufacturing.
- Learned about materials, with a focus on **metallurgy** and **compounds**.
- Learned about **drawing, stranding, and extrusion**.
- Discussed various **finishing operations** including **cabling, armouring, taping, strand-filling**.
- Discussed the different types of **testing and QA** including **qualification tests, material tests, in-process tests, finished product tests**.
- Reviewed **Nexans' products** and identified the different manufacturing processes they undergo.



Q & A





Thank you for your attention!

Contact:

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www.nexans.ca

