ICEPE-ST 2019 Kitakyushu, Japan

Vacuum Switchgear;
Past, Present, and Future

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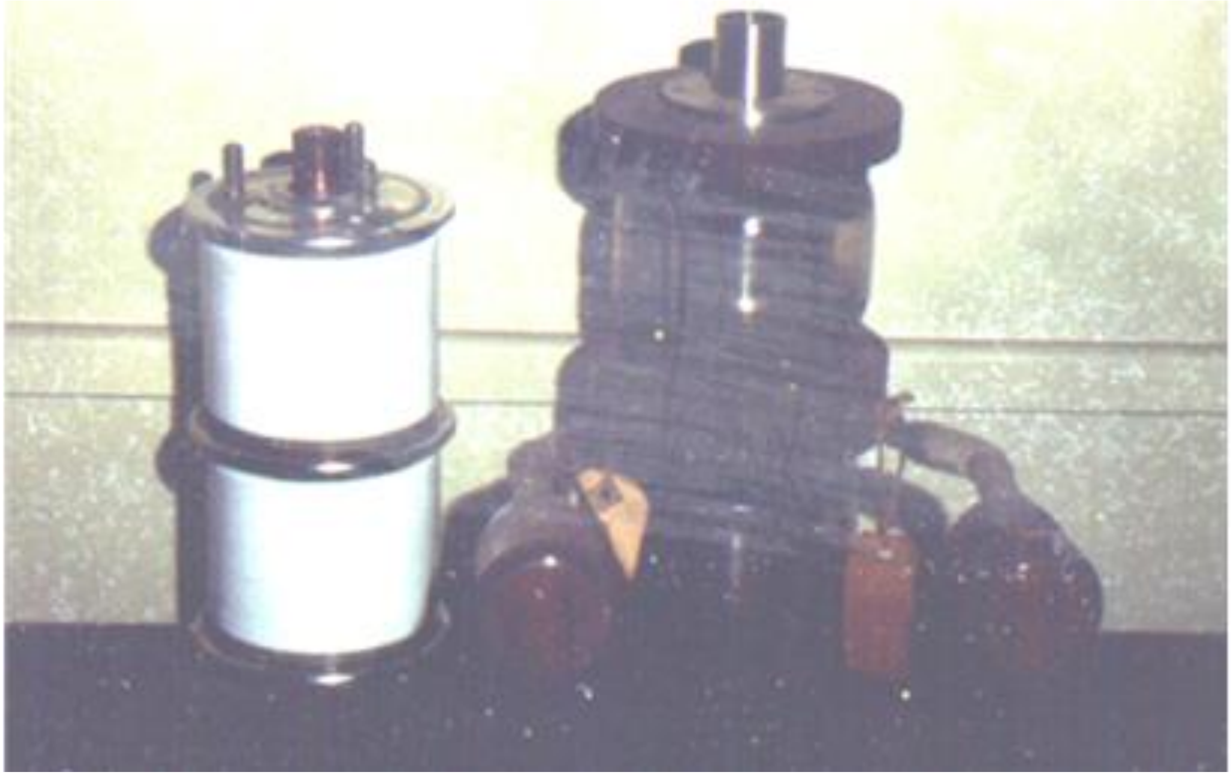
Overview

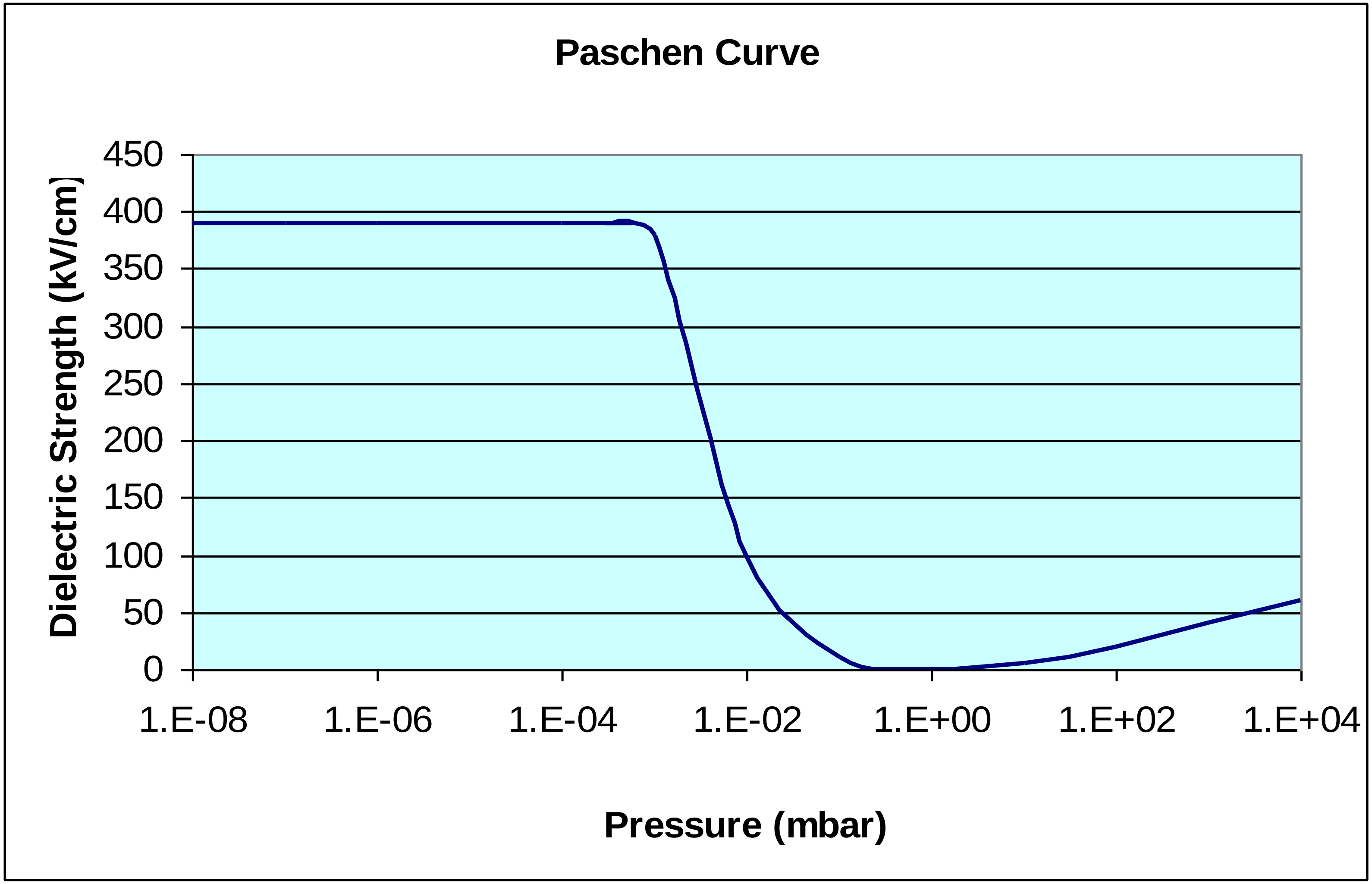
- *Introduction*
- *Vacuum Interrupter Technology*
- *A Short History of VI & VCB Development*
- *The Future*

Introduction

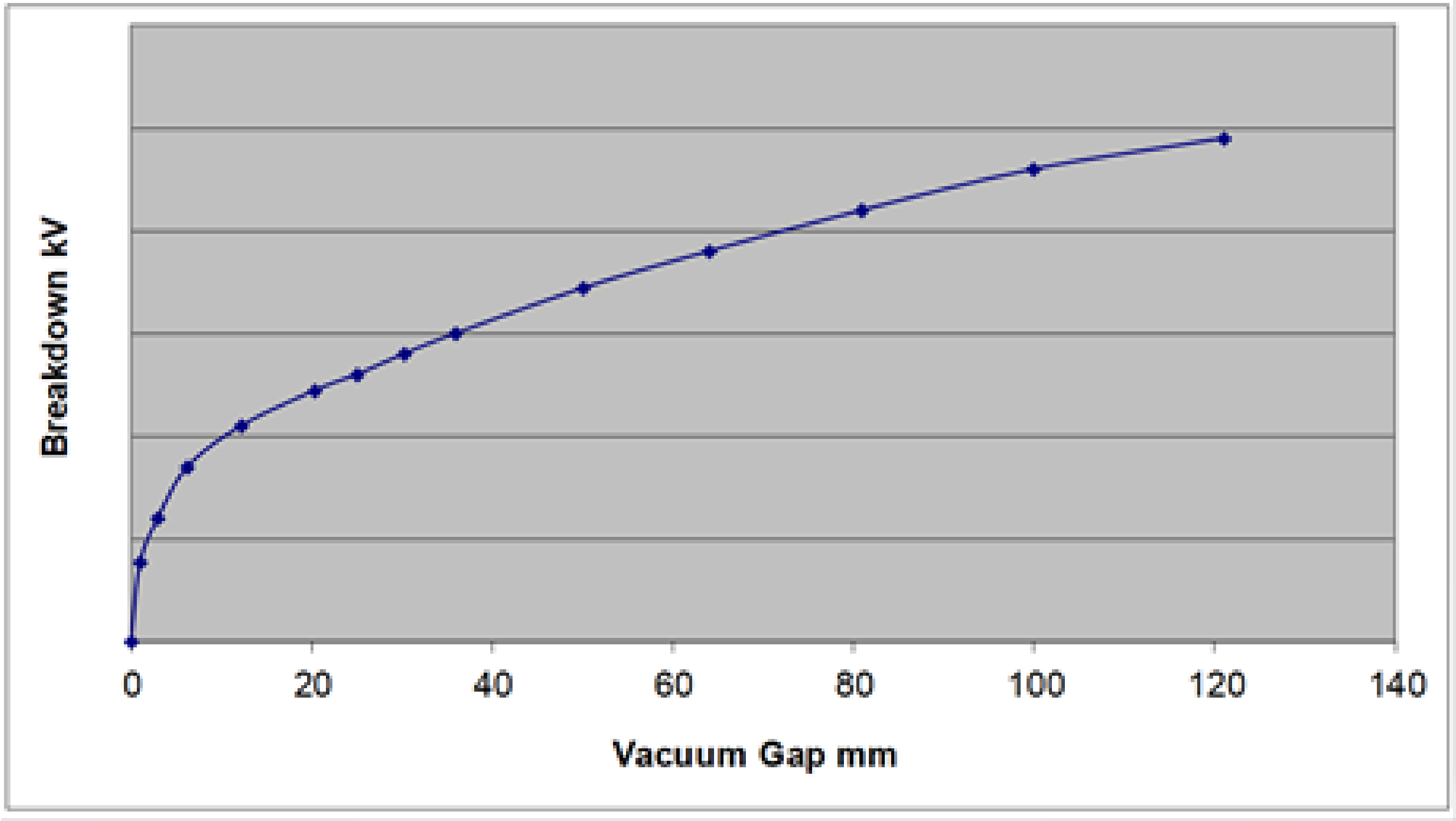


World's First Contrate VI (right), 1966

Vacuum Physics

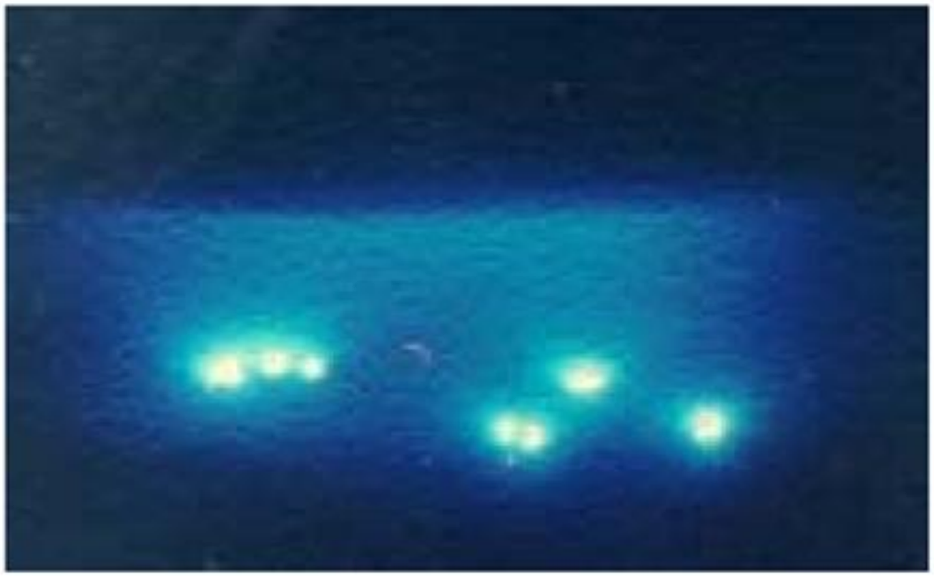


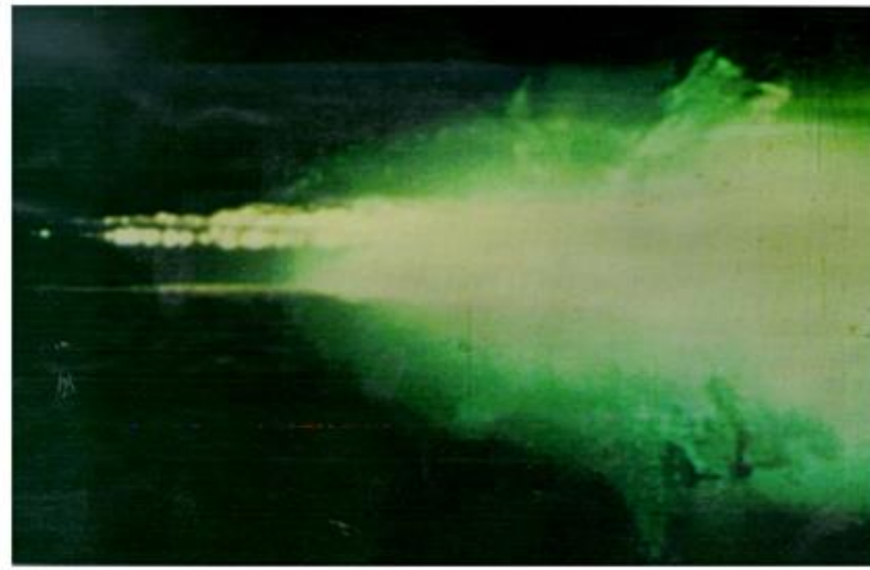
Vacuum Physics



Voltage Withstand v Vacuum Gap

Vacuum Arcs: The key Problem





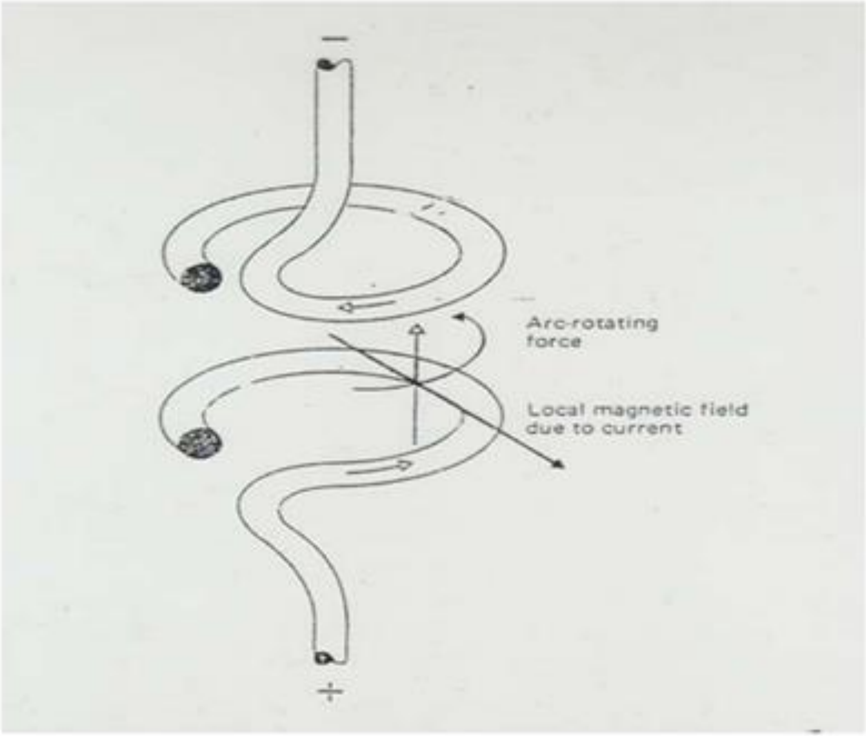
Natural Diffuse Arc <7kA pk

200A@12kV. Energy in well behaved Cathode Spots

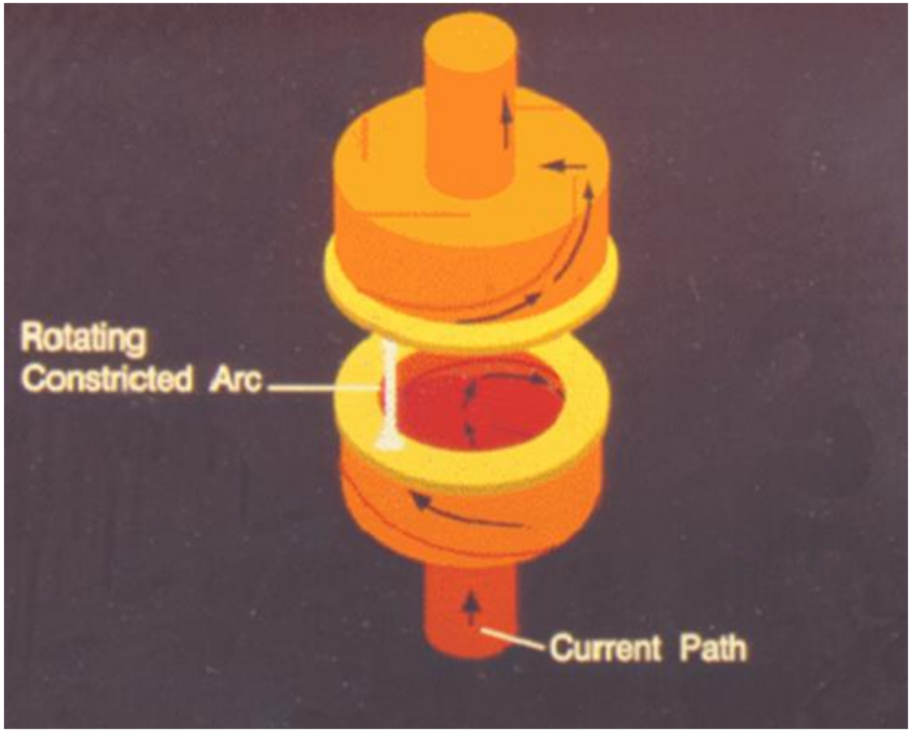
Constricted Arc >7kA pk

15kA@12kV. The liquid seen is boiling chromium and copper

Radial Magnetic Field - RMF

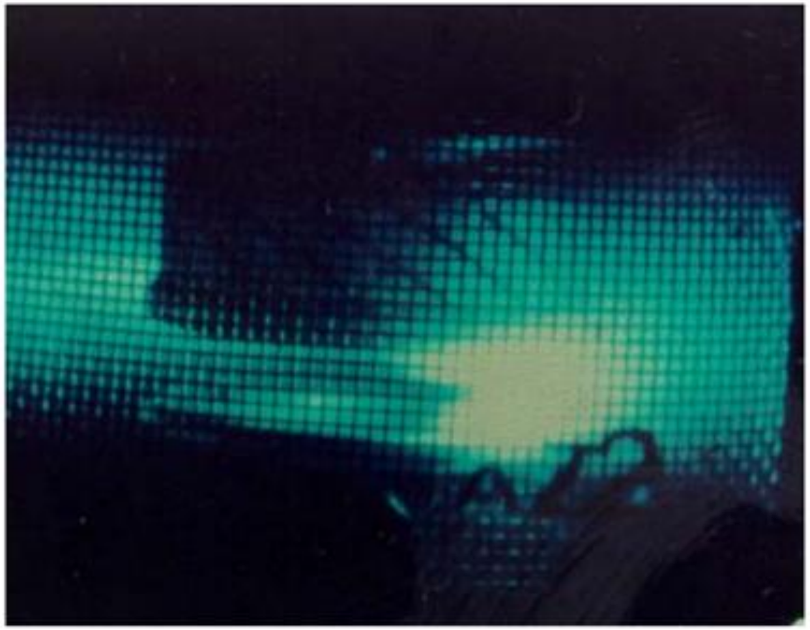


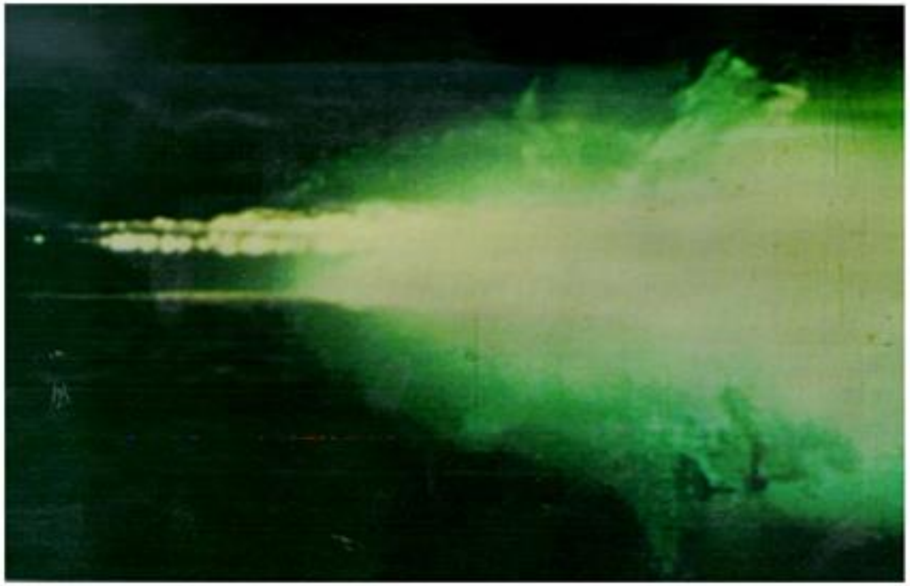
RMF Principle of operation



RMF contact geometry (Folded Petal) showing current flow

Radial Magnetic Field - RMF

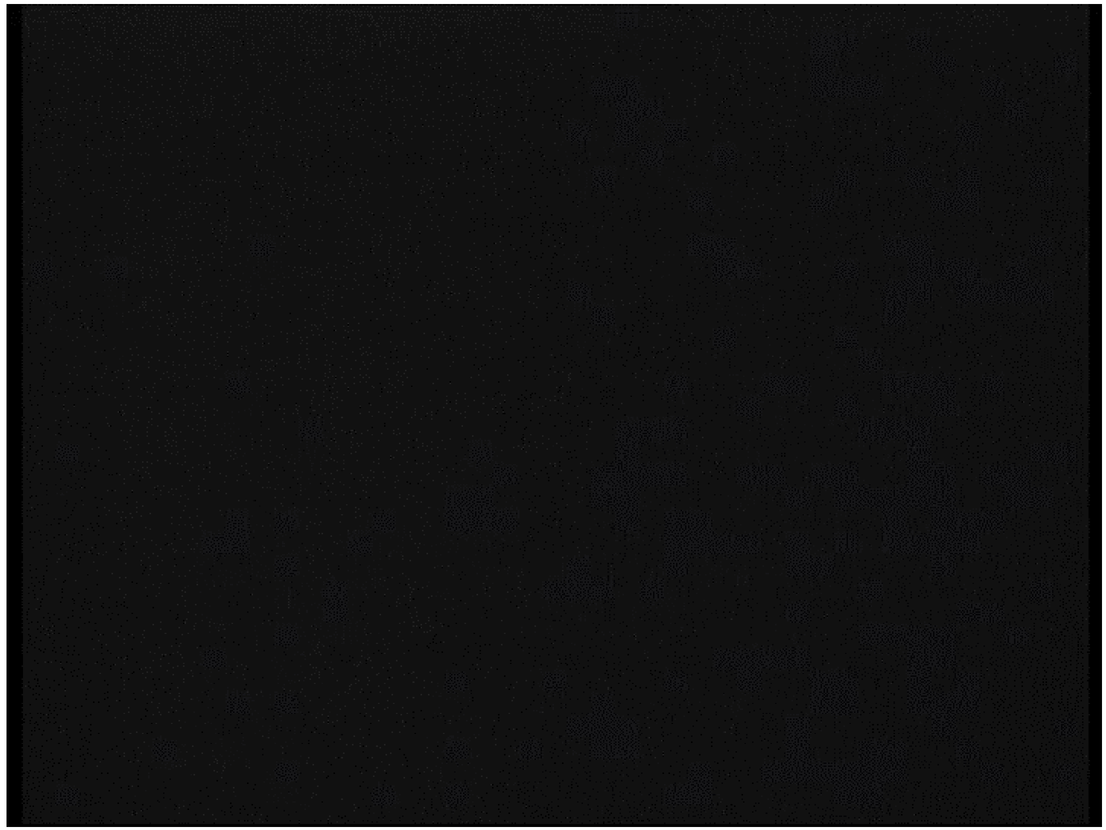




Constricted arc:
80mm diameter Contrate RMF contact. 40kA @12kV with 50% DC assymetry

Constricted arc;
No arc control 80mm diameter plain contact. 15kA@12kV.

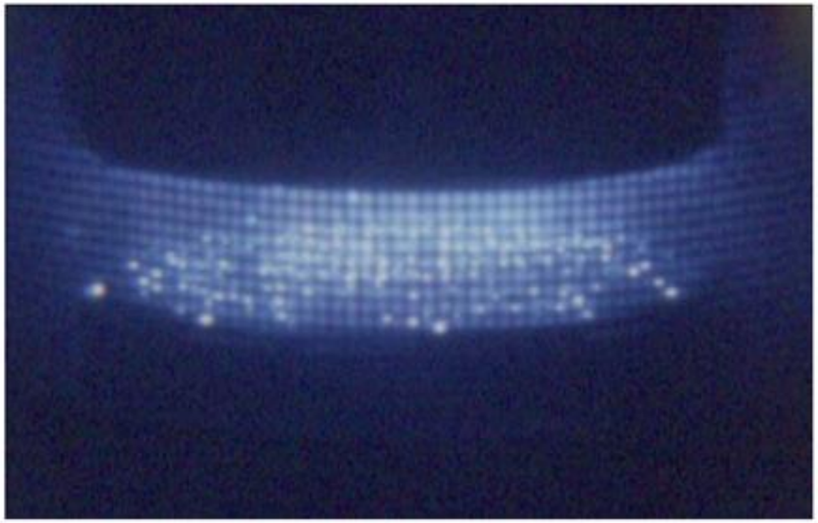
Radial Magnetic Field - RMF



Constricted arc:
35mm diameter Folded Petal RMF contact. 20kA @12kV with 50% DC asymmetry 8,000 fps.

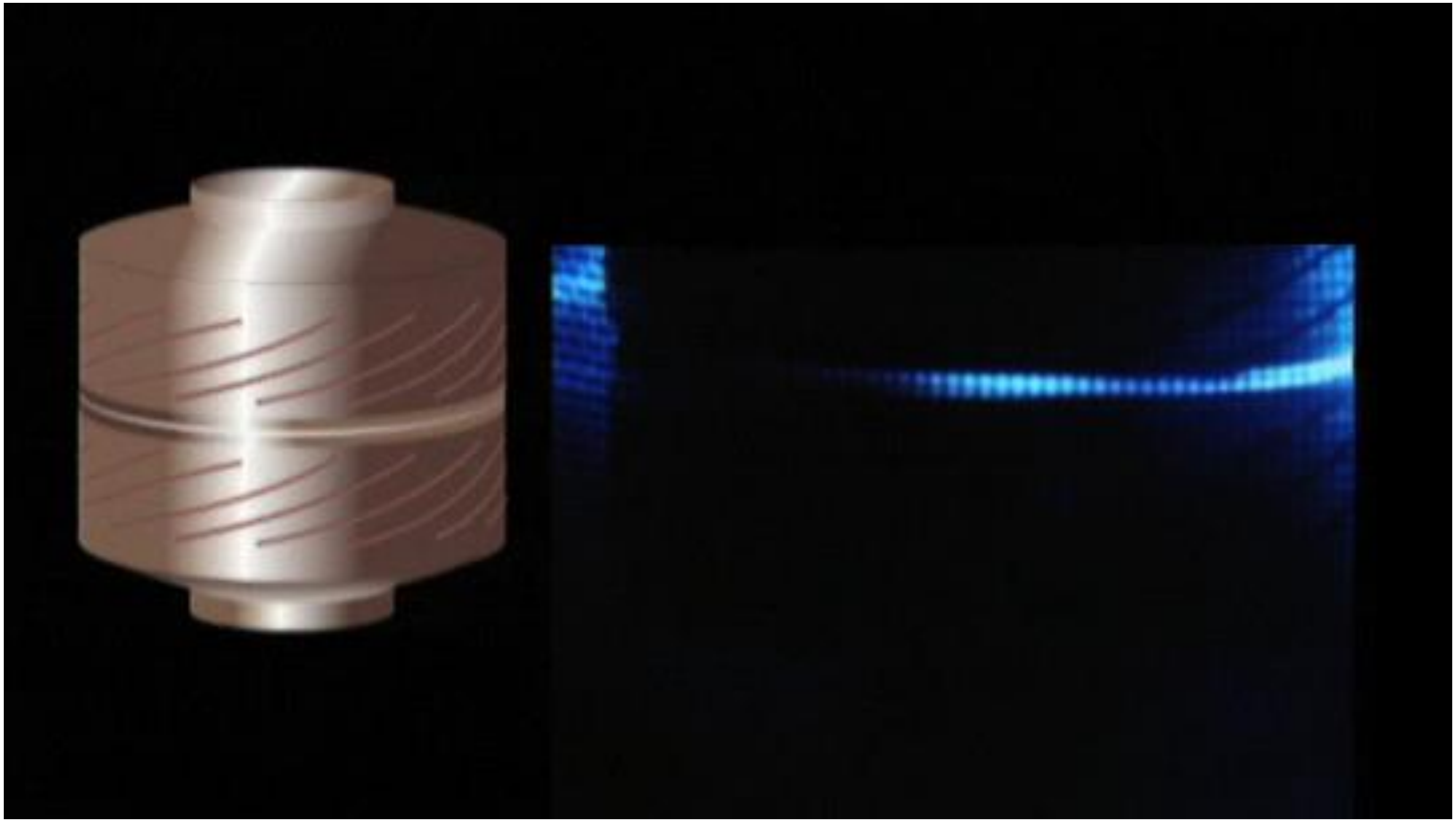
Axial Magnetic Field - AMF

AMF "Wheel" Type contact



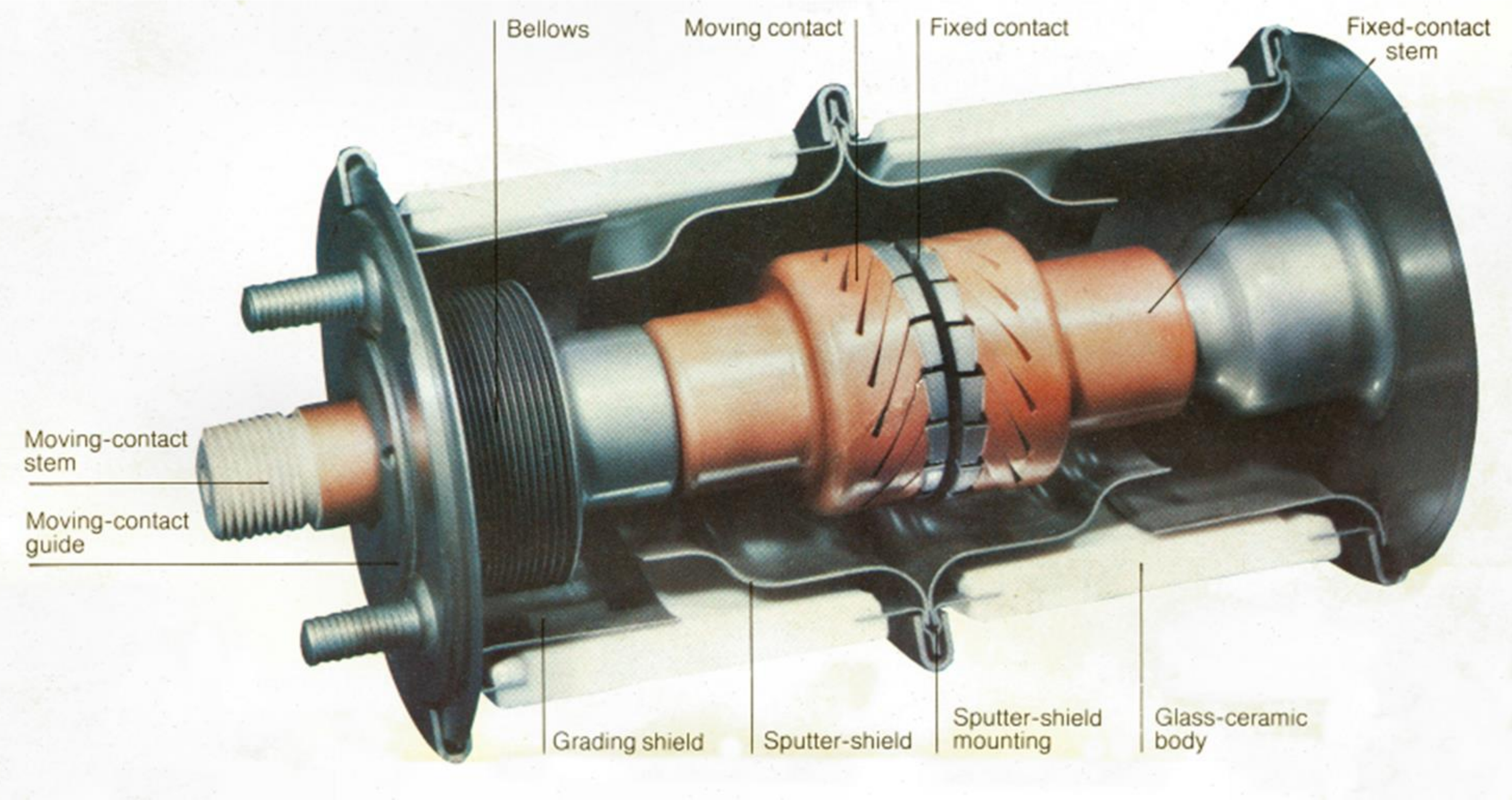
AMF contact interrupting 40kA@ 12kV

Axial Magnetic Field - AMF



"Cup Shaped" AMF contact interrupting 40kA@ 12kV (50% DC asymmetry) 8,000 fps

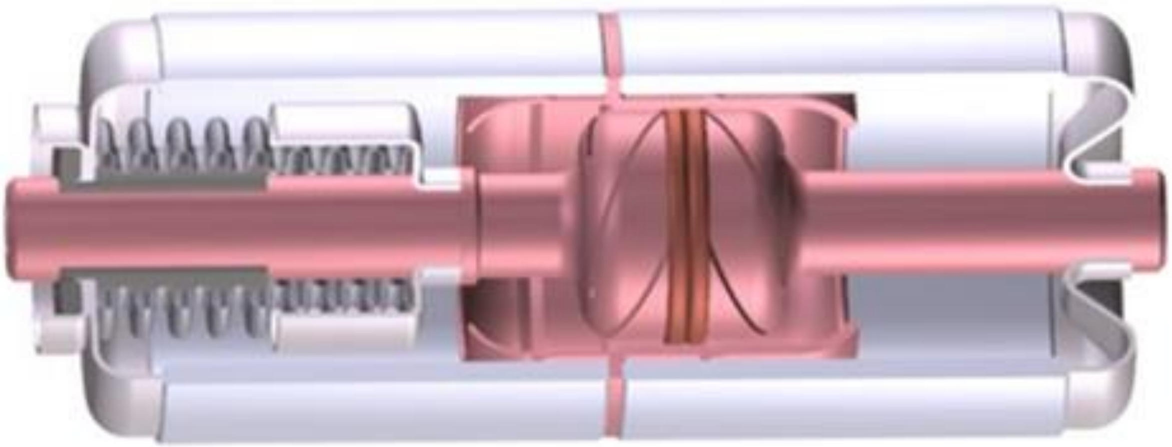
VI Construction



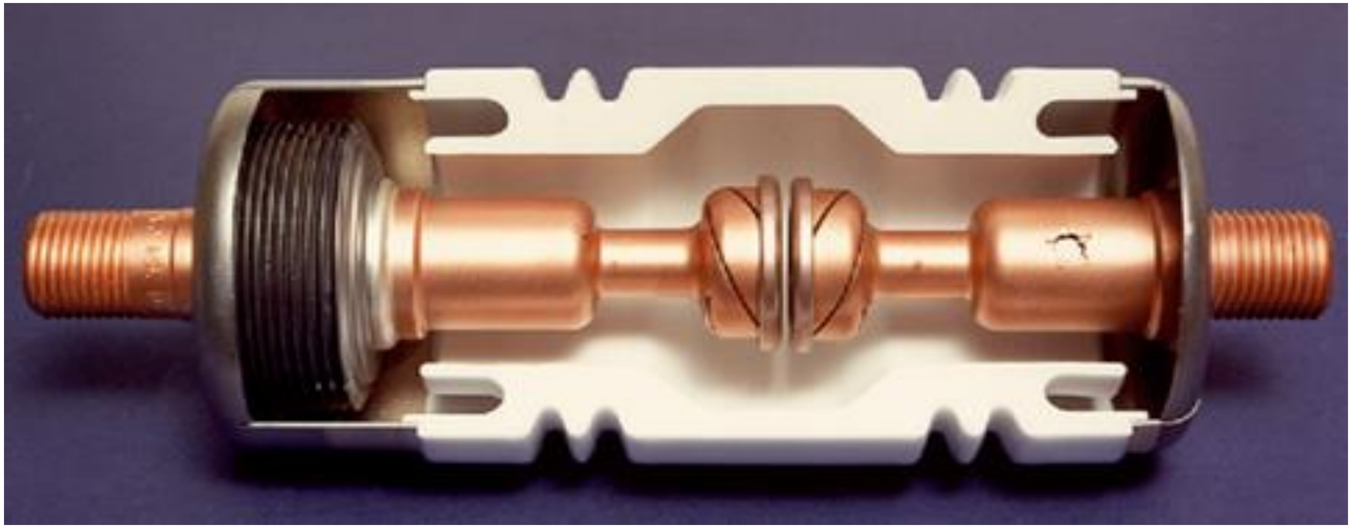
1970's Design of VI: 12kV: 25kA: 1250A

VI Construction

1990's Design Showing main features



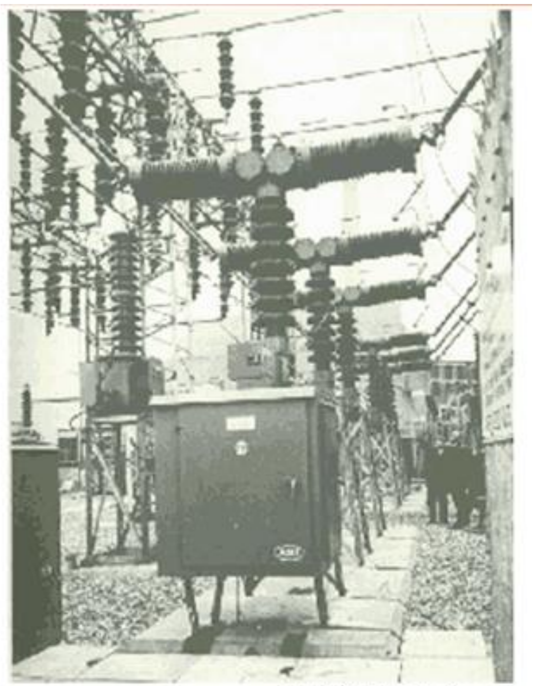
"Shieldless" variant with no vapour deposition shields

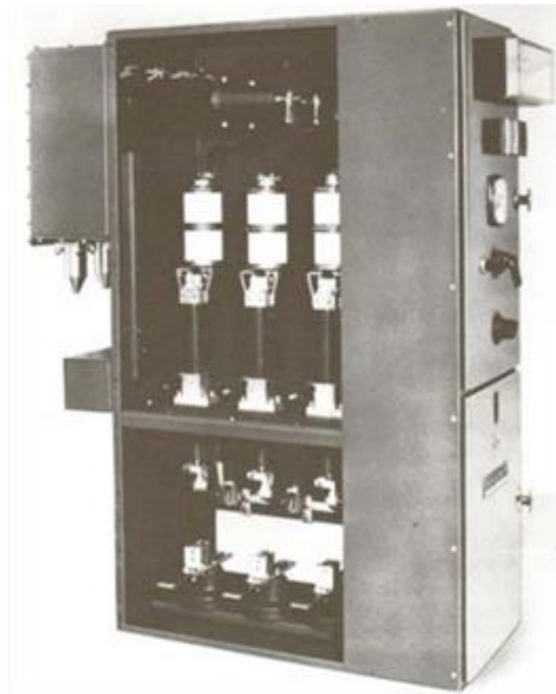


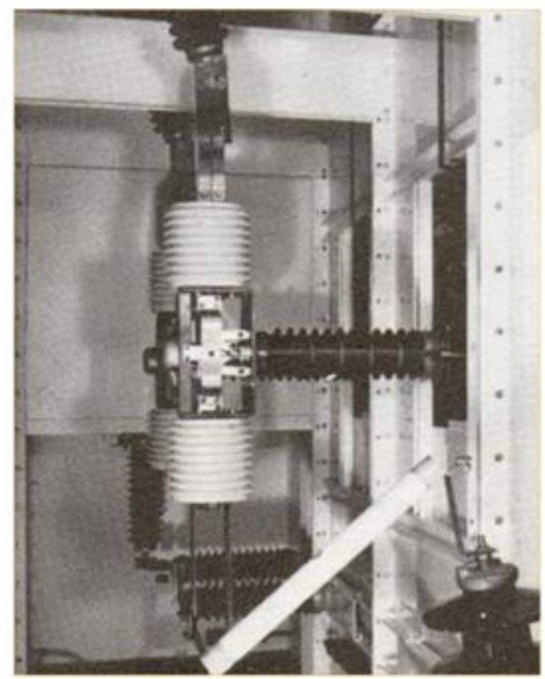
VI Construction

Evolution of VI of the same rating (12kV:20kA) from the early 1970's to the 1990's showing the effect of improved arc control on the size (and cost) of the VI. The contact for each VI is in front.

VI Construction

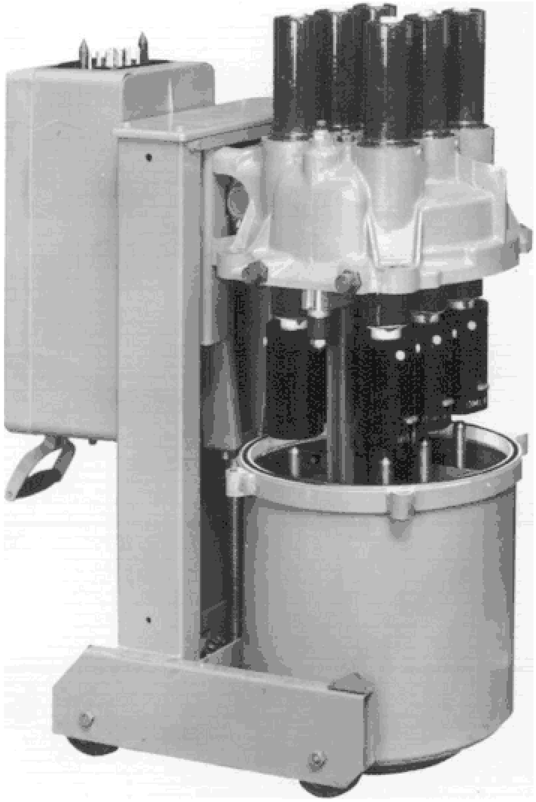






Early VCB: ***Left: 132kV Breaker in London 1968.***
Centre: 12kV Fixed Pattern VCB
Right: 25kV single phase railway VCB.

VI Construction



Early VCB: ***Left: VMX truck with "Shieldless" VI***
Right: BVP17 truck by GEC, Bulk Oil Breaker

Both units rated at 12kV, 26kA, 1250A, and the trucks were interchangeable

VI Construction

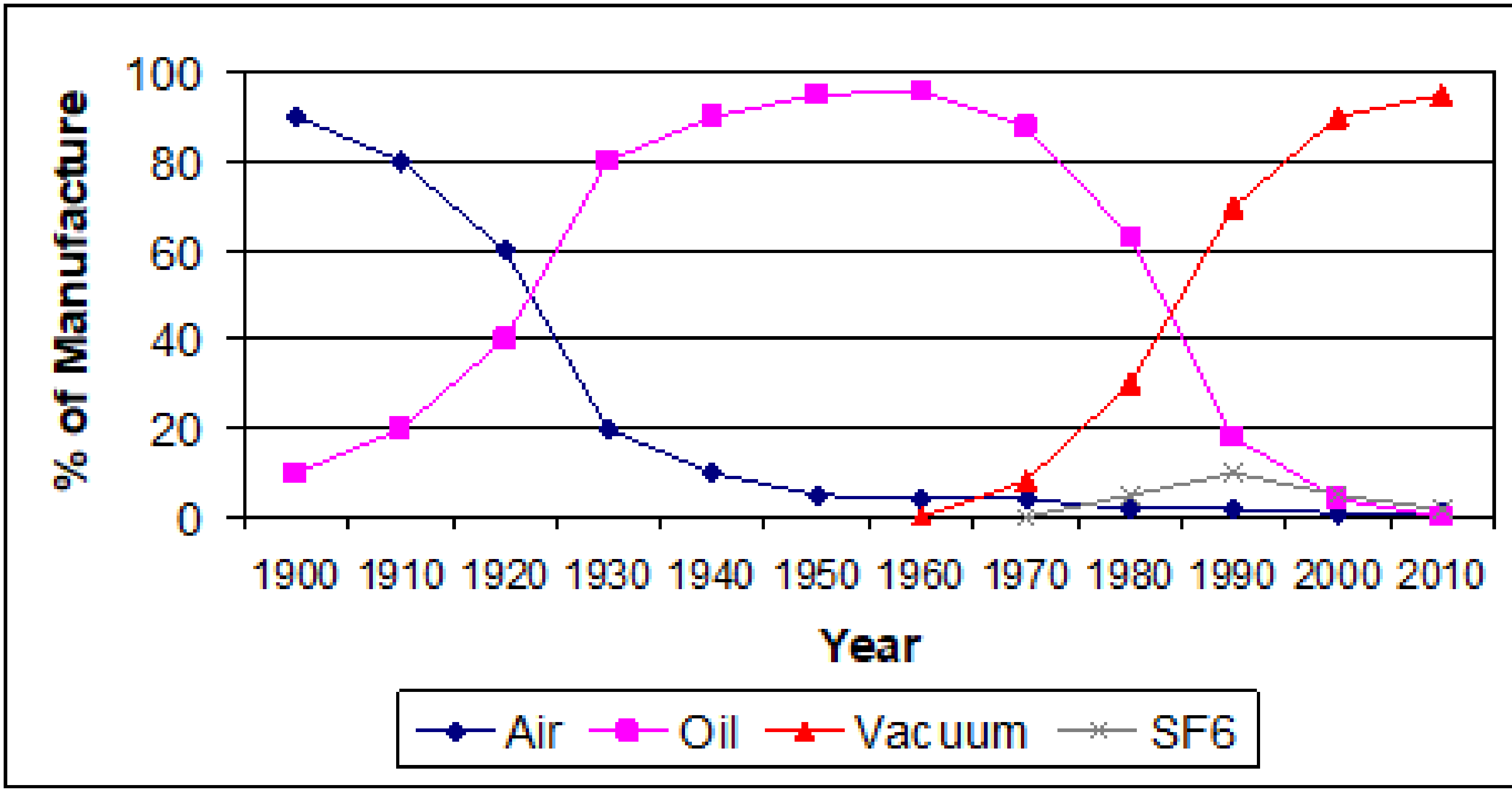
New requirements;

Left: PIX from Alstom, 12kV: <40kA: <3150A Internal Arc
Right: from Tavrida, 12kV: 25kA; 1250A Internal Arc

VI Construction

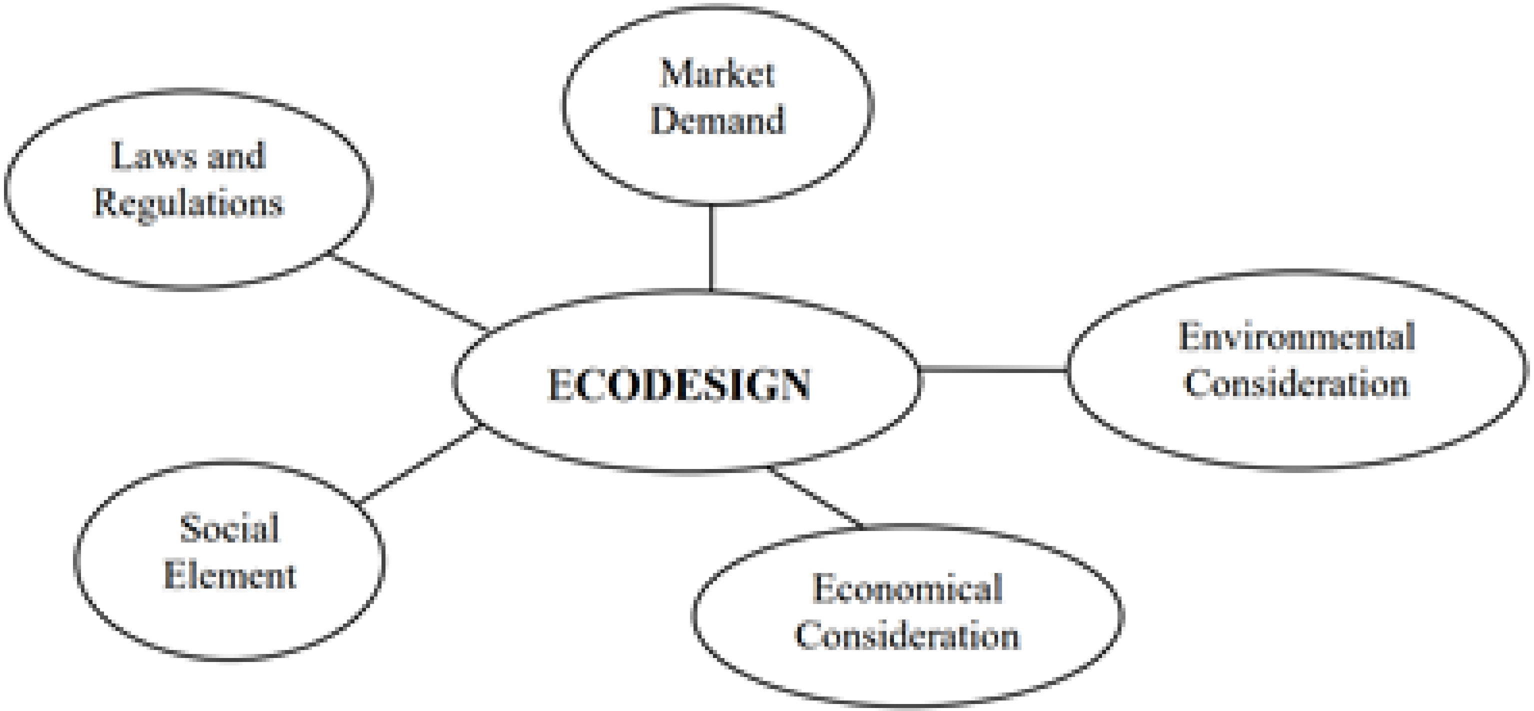
JAEPS 145kV Live Tank single break VCB on left with the Author and VI. On the right Siemens 72.5kV VCB

VI Construction



Technology substitution of MV switchgear during the 20th Century

VI Construction



Considerations for ECO design – new requirements for switchgear

VI Construction

	Achievable?	Prototype	Market
• High Voltage (245kV)	Yes	2-3 years	4-7 years
• High Current (>6300A)	Yes	1-2 years	4 years
• DC Interruption (<30kV	Yes	2-3 years	5 years
• LV (<1kV)Low cst	Yes	2-3 years	5 years
• Smart Grid (smart devices)	Yes	2-5 years	6 years
• MV Low cost & size	Yes	1-2 years	3-4 years

VI Construction

	Achievable?	Prototype	Market
• *High Voltage (245kV)*	*Yes*	*1-2 years*	*4-7 years*
• *High Current (>6300A)*	*Yes*	*1-2 years*	*4 years*
• *DC Interruption (<30kV)*	*Yes*	*2-3 years*	*5 years*
• *LV (<1kV) Low cost*	*Yes*	*Done*	*Done*
• *Smart Grid (smart devices)*	*Yes*	*1-3 years*	*4 years*
• *MV Low cost & size*	*Yes*	*1 year*	*2-3 years*

Conclusions

- ***Over the past 60 years great advances have been made from all parts of the world to vacuum switching technology***
- ***As a result Vacuum Cirucit Breakers dominate the MV market and are moving into both the LV and the HV markets.***
- ***Vacuum switchgear not only has outstanding technical performance, but also has excellent environmental compatibility***
- ***It seems that the future for Vacuum Switching is bright***

Final

Questions?

Final

Dr Michael P. Reece; 1926 - 2019