

Overhead or Underground A Comparison

Harry Orton

OCEI

Vancouver, Canada

Presentation Outline

- Professional Background
- Professional Experience
- Video
- Advantages of Underground Cables
- Disadvantages
- Photographs OH Lines and UG Cables

Professional Background

- Engineer-in-Training 1960
- NESCA climbing poles, underground cables
- Part-time Bachelors Degree UNSW 1966
- Masters Degree UBC 1969
- Thesis topic: Series Comp. of OH Trans. Lines
- PhD UNSW UG Cable Diagnostics
- BCHydro Research 1977, Corona Loss, RI and TVI Studies of Transmission Lines, UG Cables
- Consulting Engineer 1994

Litigation Experience

- KEPCO Korea
- HYLSA Mexico
- PG&E San Francisco, 230 kV, Tri-Valley Project, Pleasanton, San Raemon
- US Department of Justice, NY, Cross Sound, 150 kV Subsea HVDC Light.
- Singapore Power, PowerGrid, 230 kV XLPE cable.



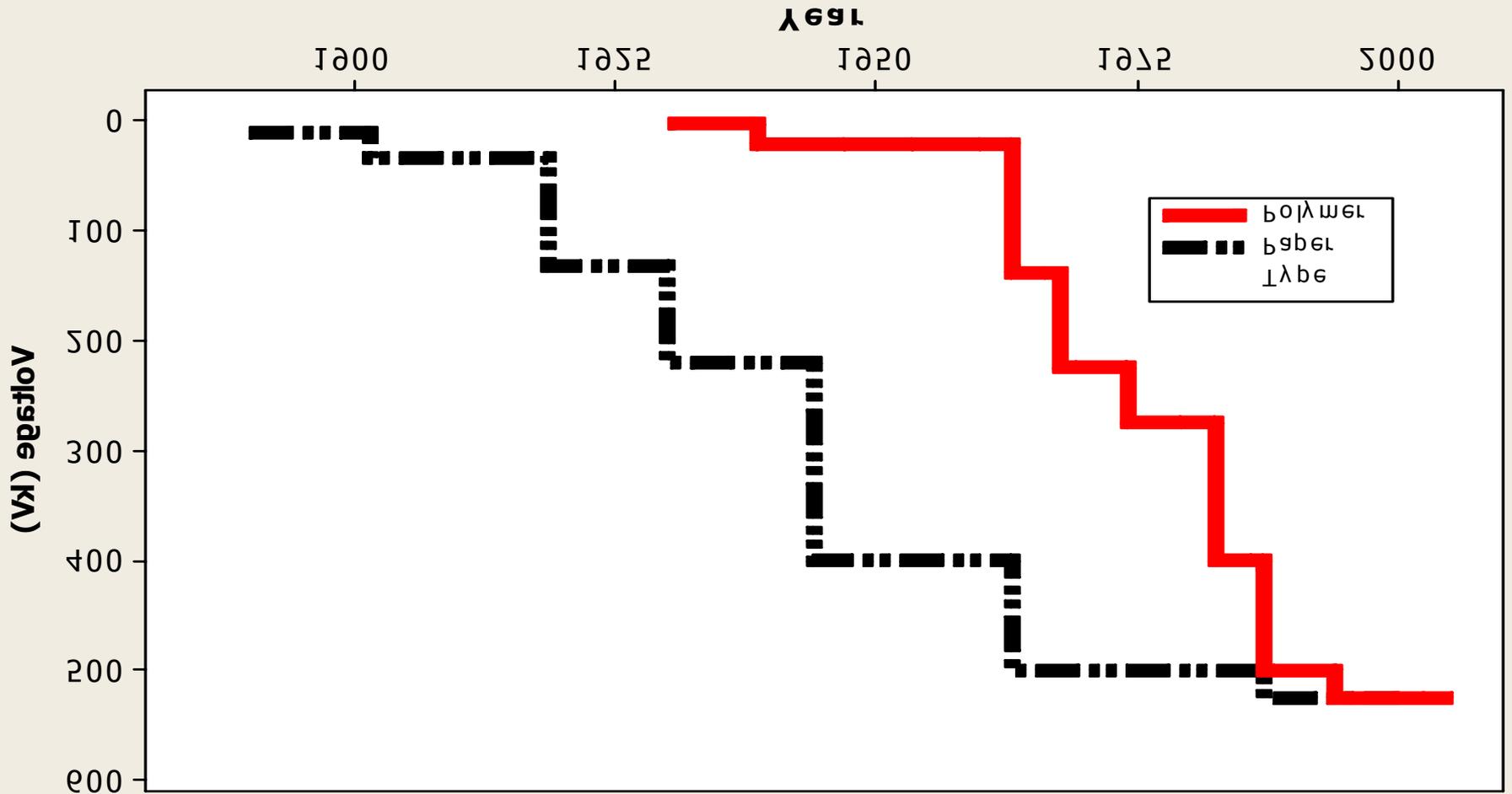
Professional Experience

- Seminars UBC and Worldwide since 1990
- Published over 40 papers on OH and UG cables
- IEEE, Insulated Conductors Committee (ICC)
- Chairman of Transnational Committee
- Chairman of Task Group A2D, Cable Shields
- Chairman of Task Group B15D, Accessories
- Co-chair of Task Group C27D, Joint ROW

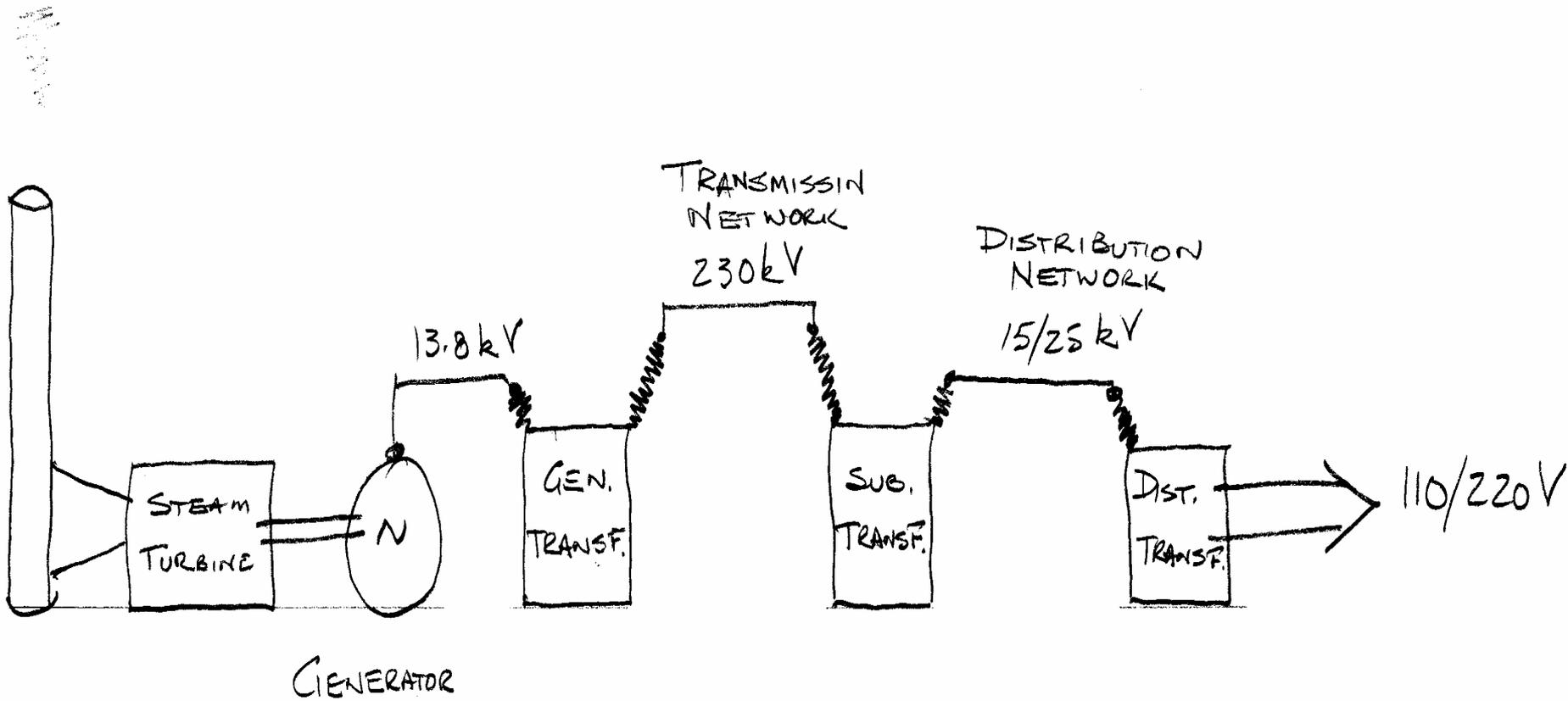
Professional Experience continued

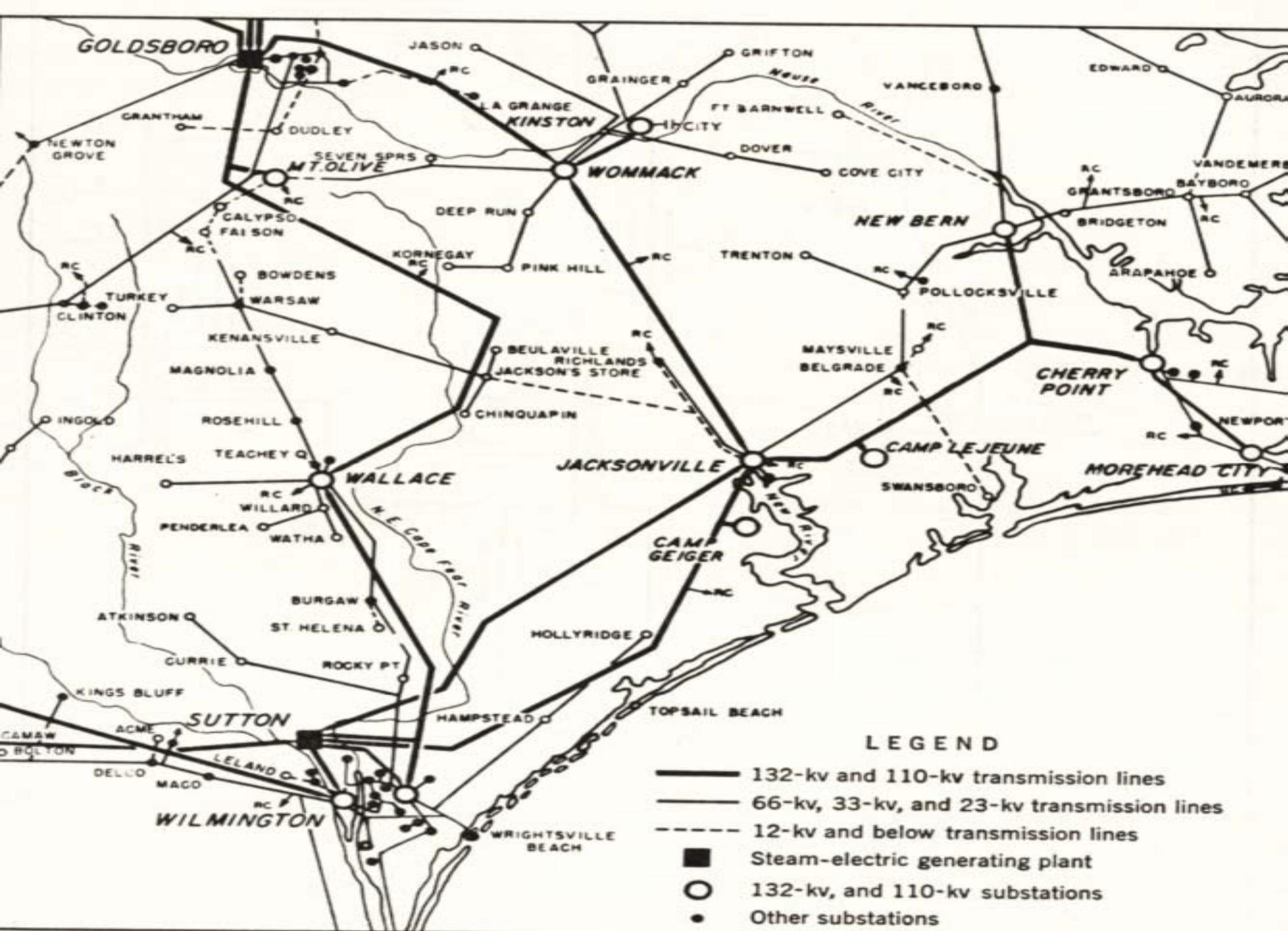
- Registered Professional Engineer in the Province of British Columbia, Canada
- Listed as a consultant for Alberta and BC Civil Trial Lawyers Associations
- The World Bank
- ASTM

Underground Cable Historical Perspective



BASIC POWER SYSTEM DIAGRAM





Underground Power Cable Systems

- New York City – no overhead since 1890's
- Singapore - 100% underground
- The Netherlands – Distribution 100%
- Belgium ban on OH Lines since 1992
- Denmark replaced six 132 kV OH lines with two new 400 kV UG cables in 1997 and 1999
- December 1999 storms in France caused many blackouts-new policy 25% HV lines are UG

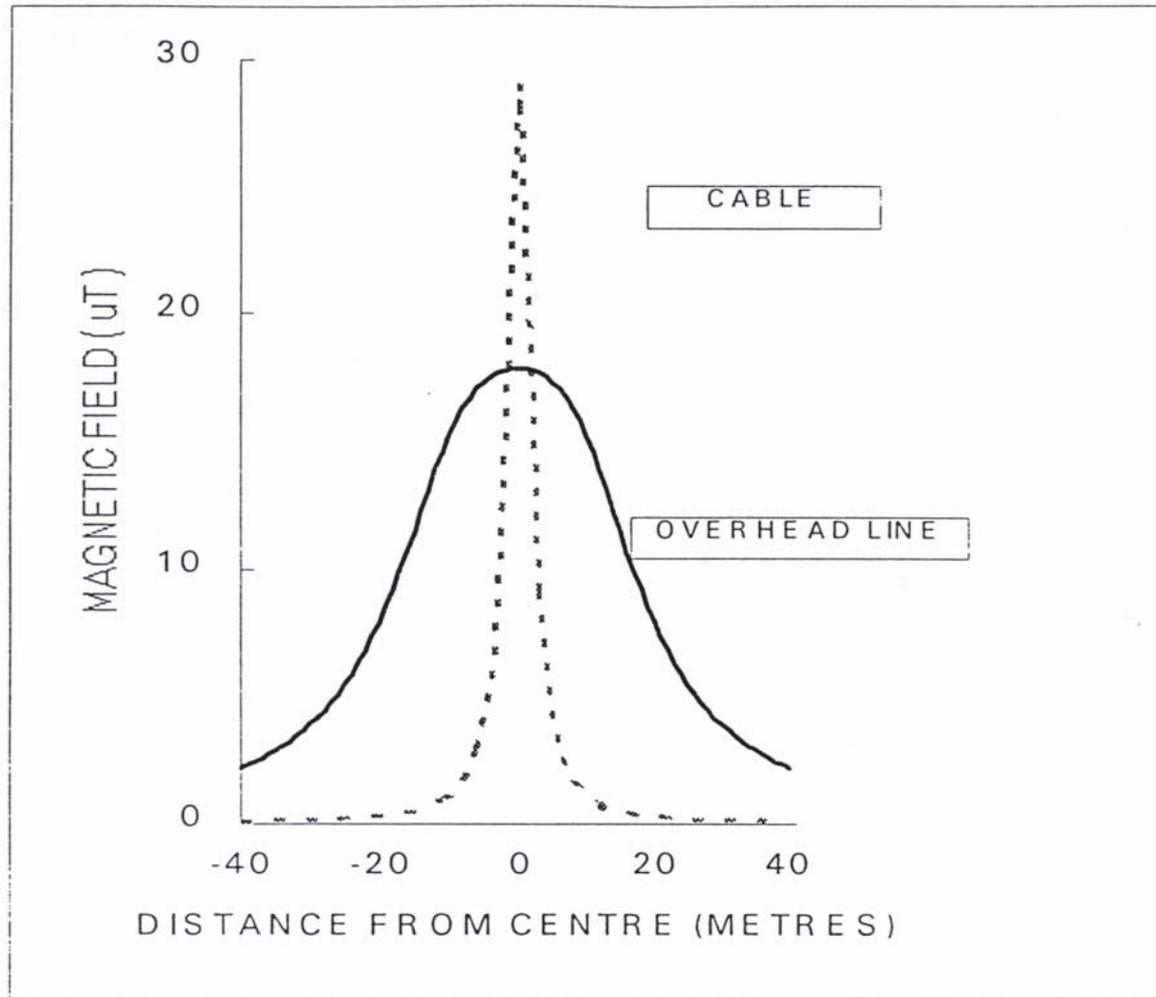
Underground Power Cable Systems Continued

- Connecticut Underground Power Line Legislation Approved
- “Overhead Lines Need a Quick Burial” in Atlanta Journal Constitution
- Two major developments cancelled in Atlanta one for \$150M and the other \$100M

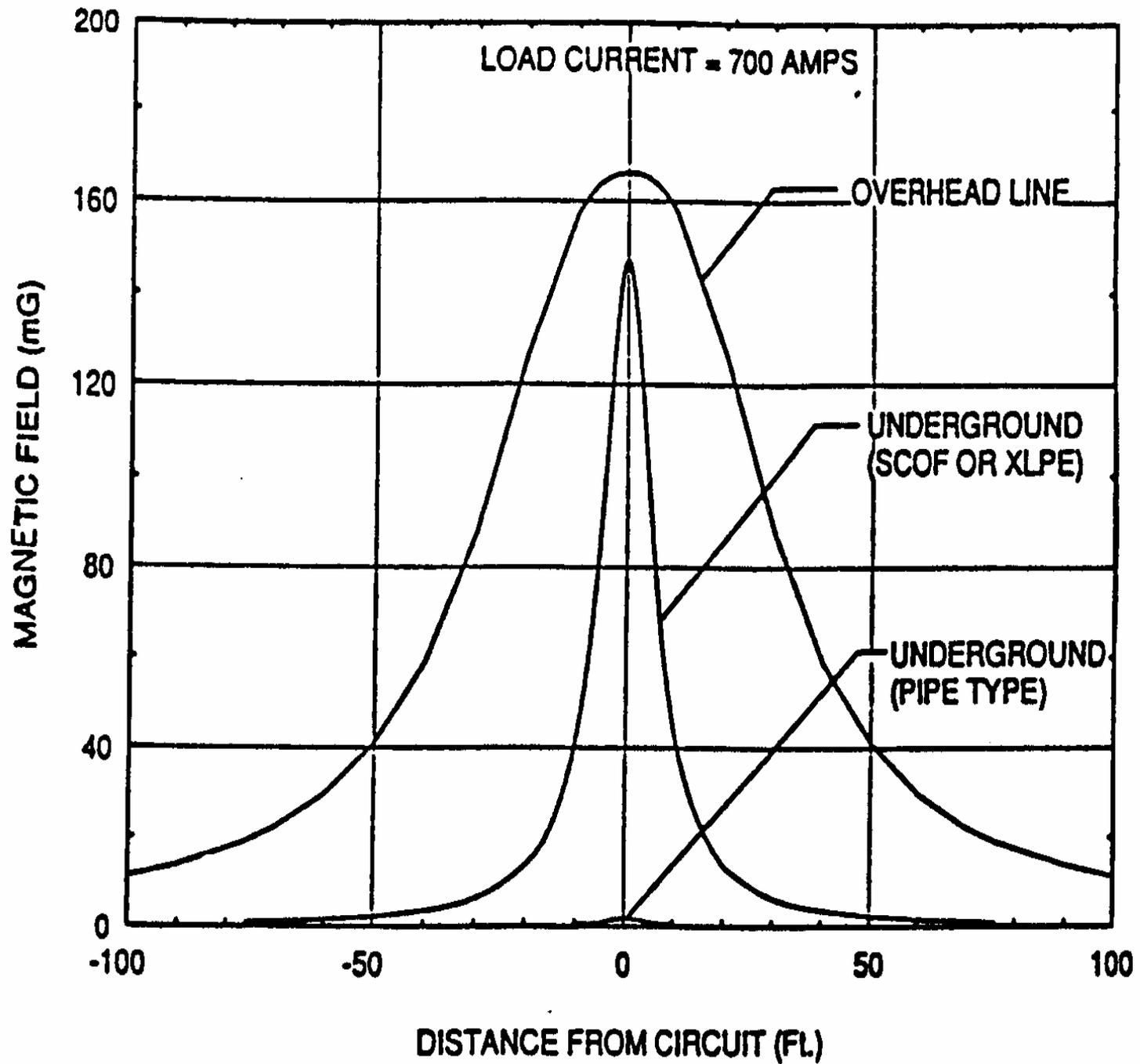
Advantages of UG Cables

Environmental

- Minimal visual impact
- Low EMF
- No corona discharge, RI and TVI
- No bush fire problems
- Minimal lightning problems
- High level of personnel and public safety, no fallen lines (France 2000, 19 contact deaths with OH lines, 0 with UG cables)
- Good working conditions



Furthermore, it has to be noted that household appliances and industrial machinery generate magnetic fields in their vicinity which may sometimes be much higher than those produced near overhead lines and cables. Indeed, magnetic fields of a tenth of a millitesla and more have been measured, for instance up against hair dryers and vacuum cleaners, and fields of even higher magnitude have been found near welding equipment and arc furnaces.



Advantages of UG Cables

Power Grid Security

- Not affected by ice, snow, rain, wind, dust, smoke or fog
- Not affected by Ice storms, Tornadoes, Hurricanes
- Nothing to be stolen

Advantages of UG Cables

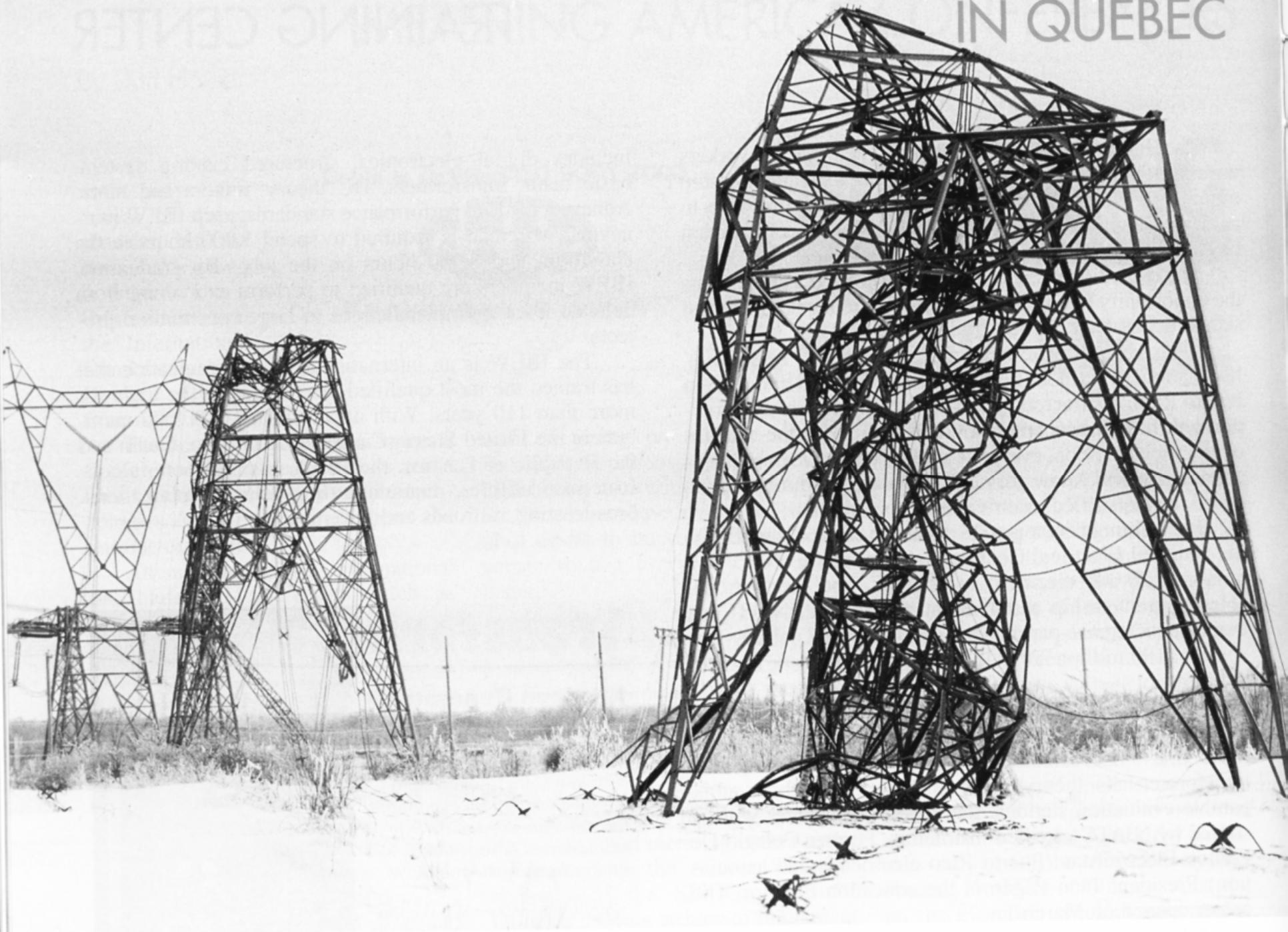
Power Grid Security Continued

- French storms in 1999, 8% of OH lines out of service, 90% of substations back in service after 4 days
- 6 months to complete repairs to the lines
- Total cost of damage Euro1.3 Billion
- No estimate for economic losses
- Interruption lasted 15 million customer-days

Advantages of UG Cables

Power Grid Security Continued

- Quebec ice storms in the winter of 1998
- Hydro-Quebec hundreds of kilometres of EHV and HV lines collapsed
- Thousands of towers
- Blackout initiated by OH line at First Hydro in Ohio



TRAINING CENTER

IN QUEBEC

Advantages of UG Cables

Economy

- Low maintenance costs
- Land use minimized
- Value of land and buildings unaffected

Advantages of UG Cables Operation

- High reliability and availability
- Few faults, bumps on power system
- Major blackouts in NE
- Diagnostics available to locate problems

Table 5: Benefits from undergrounding of electricity lines

Benefit type	Beneficiaries			
	Utilities	Customers	Local residents	Wider community
Reduced electricity price (from construction of missing electricity links)	√	√		√
Reduced transmission losses	√			√
Lower maintenance costs	√			
Improved electricity service		√		
Reduced storm damage	√	√		√
Reduced accidents (inc. wildlife electrocutions)			√	√
Improved views/property values			√	
Health & Environment (e.g. noise, EMFs, vegetation management)			√	√

Source Study Ref. [16]

Disadvantages

- Cost, must consider life time costs not just initial
- Cost differential decreasing with time
- Cost of losses (30-60% less than OH), maintenance and repair
- Undergrounding 25% of the existing EHV and HV lines in Italy and the UK will increase the price of electricity by 3-5%
- Undergrounding all of the lines in Italy would increase the cost of electricity by 16%

Disadvantages

- Outage time, locate fault and repair(OH one day, UG 7-10 days)
- Fault location instantaneous, can have longer repair time
- Continuous trench required (sensitive areas, directional boring)
- Soil thermal conditions modified

Disadvantages Continued

- Presence of vaults and manholes
- Distance limitation 100 km for ac cables
- HVDC Light 600 km - planned
- Murray Link 177 km – longest in the World
2002

Increasingly cables are being seen as the lowest cost solution for reliable delivery of power. This recognition is seen in the increasing use of cables within utilities. Within Europe the total amount of underground cable used has risen from 15-20% in 1960 to 40% in 1994. In Japan at 275 kV there was 11.5 % in 1980 and in 2001 there was 28%.

Region	Europe	North America	Asia / Pacific
Percentage of UG Cables to OH	40	17	9

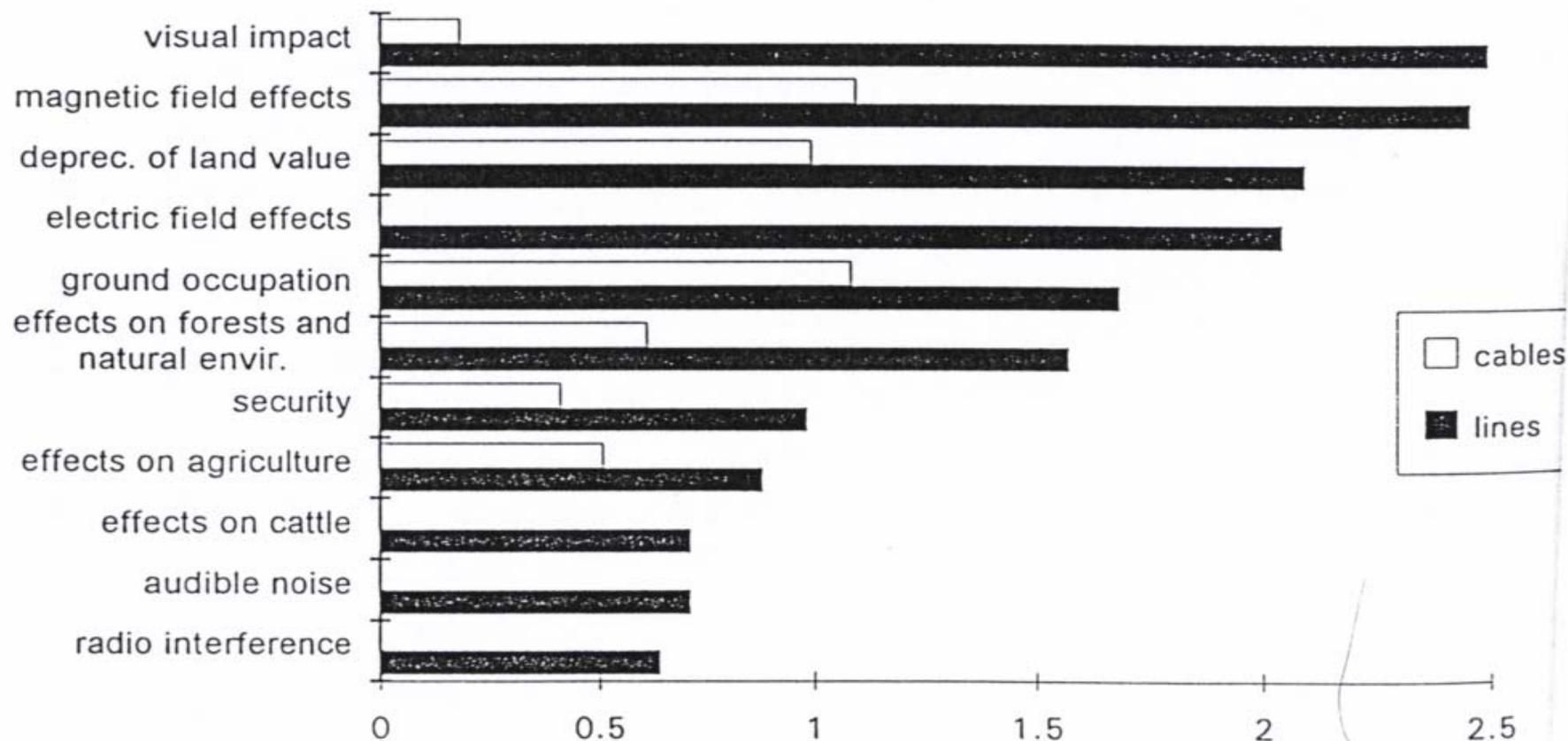
Table 1 Amount of Underground Energy Cable installed at 1994

**Table 2 Public Concerns for cables and overhead lines
(CIGRE1996 21/22-01):**

0 no importance, 1 low importance, 2 high importance, 3 compulsory

Concern	Rating for Overhead	Rating for Cables
Visual	2.5	0.2
Magnetic Field	2.5	1.1
Land Depreciation	2.2	1
Electric Field Effects	2.1	0
Ground Occupation	1.7	1.1
Security of Supply	1.6	0.4

Points of greatest concern about lines and cables



It is interesting to note that, despite the fact that public opinion often asks for replacing overhead power lines with underground cables, about 60% of the countries have declared they are facing protests against cables and in about 40% of the countries these protests are followed by legal actions.

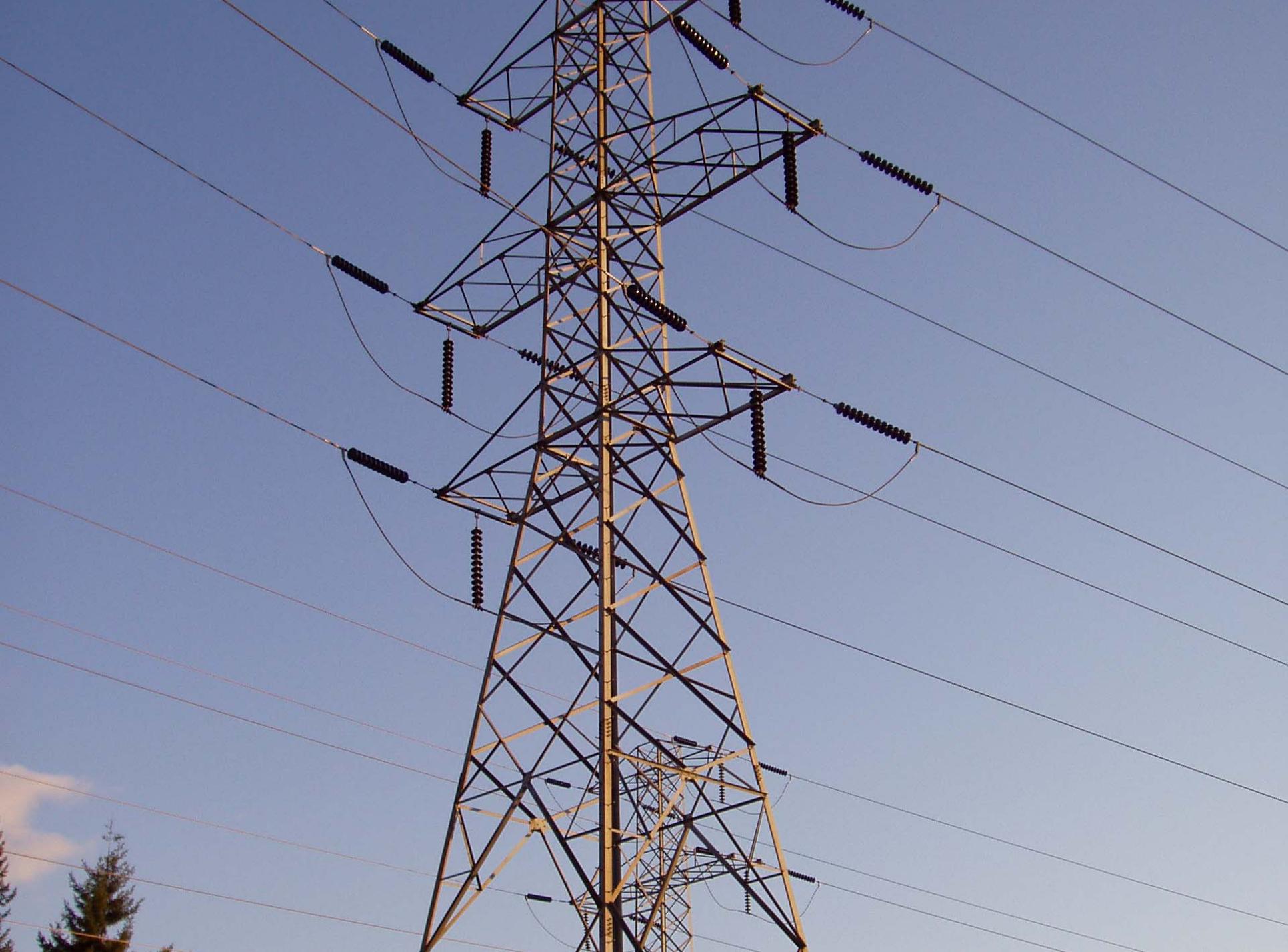
Table 3 Cost ratio of UG cables to OH lines

Voltage (kV)	Based on Installation Cost	Based on Lifetime Costs
20	1.2-1.5	1
66	3	1.5
132	5.7	2.6
225	5-10	N/A
400	5-10	N/A











CHARLES ST
3700

A-Z Europe
Auto Care
BODY SHOP
I.C.B.C. Repairs

PAUL'S METAL
SERVICE INC.
CHINESE COOKING
EQUIPMENT
TANDOOR OVENS
SUS
CUSTO

POLAR
BATTERY

THE CH

APPLY

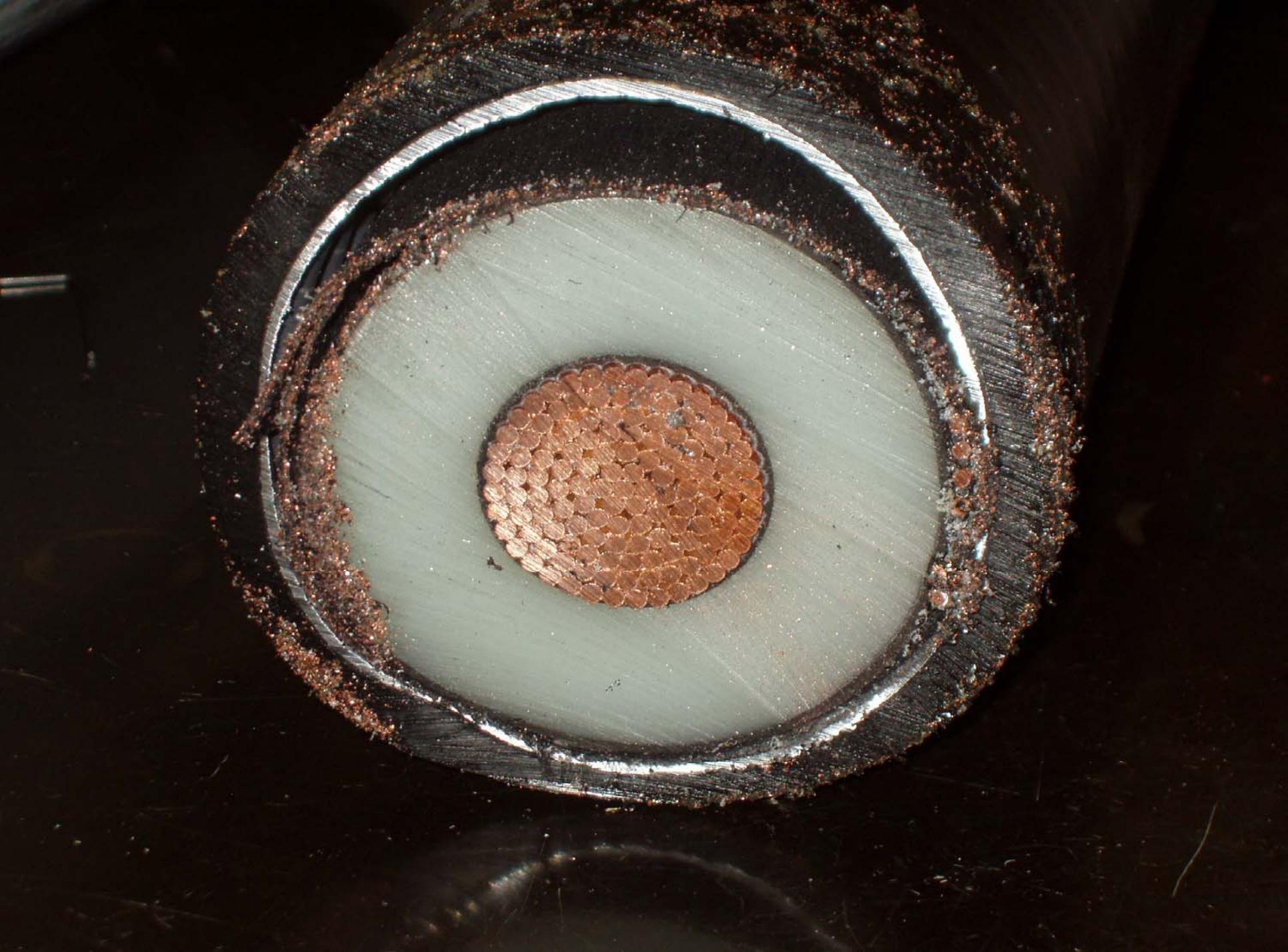
MAKE & FINE
4888

































Inverness St.

Riviera City

No Left Turn

Inverness

Inverness St.

