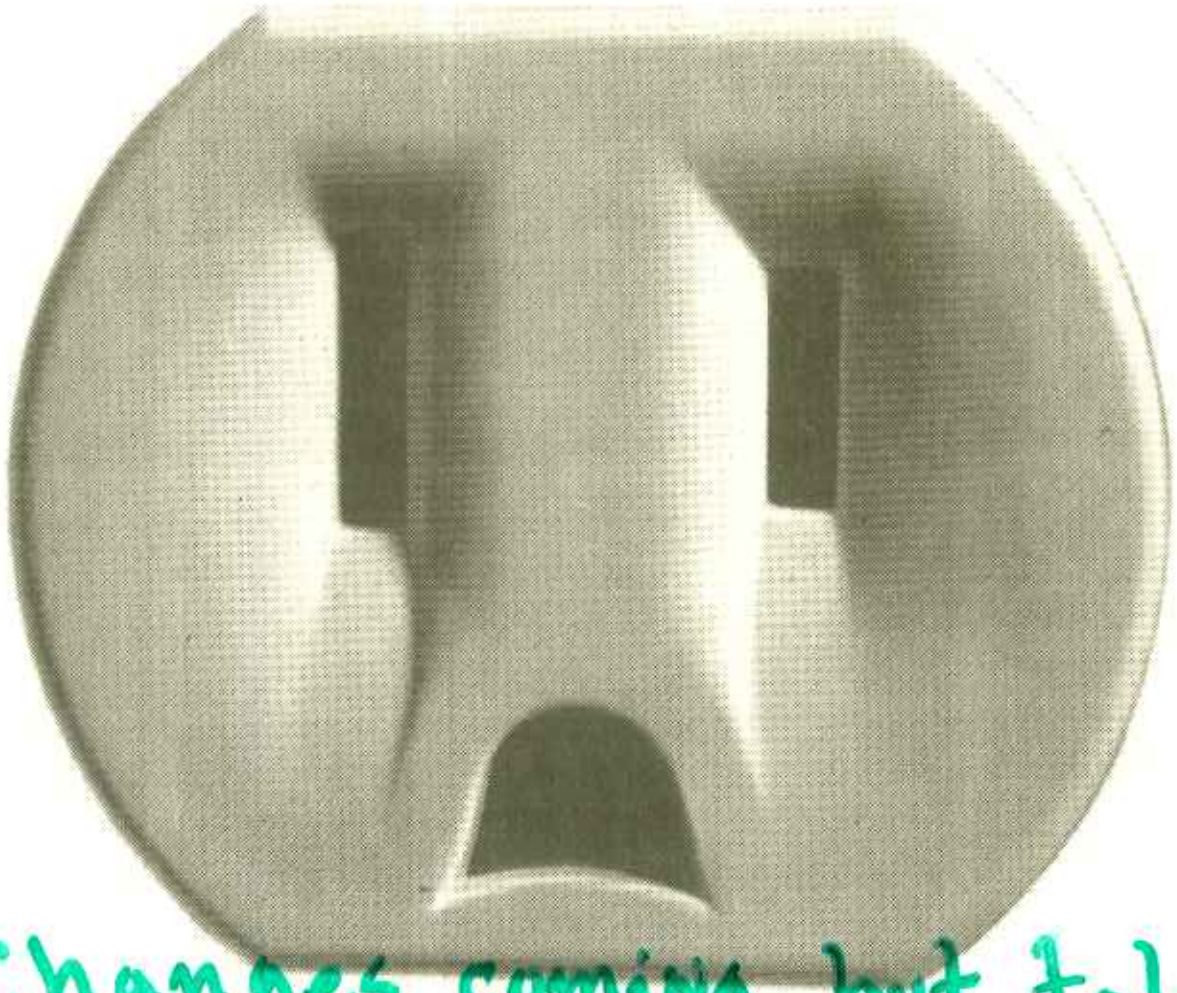
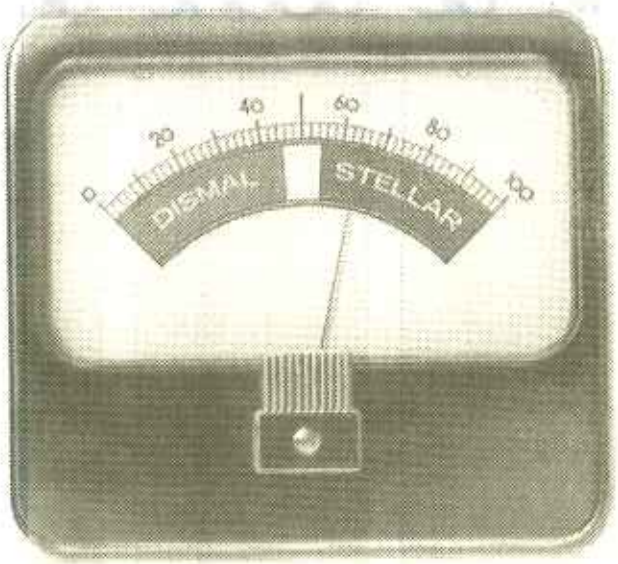
Chapter 10 #1
Transmission

- Conservation Talks Review
- Demand
- CO_2 Production
- Grid Monitor
- Transformers
  - Coil Wiring
  - Measurements
  - Parallel Transformers
- Transmission
- Grid Failures

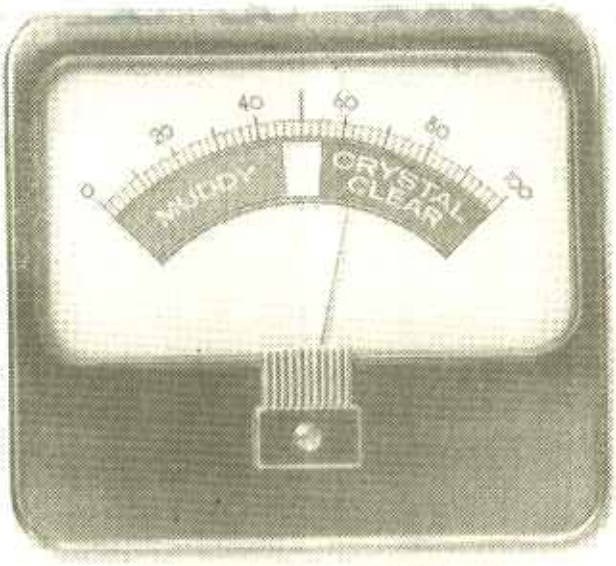
Meet Sad Socket



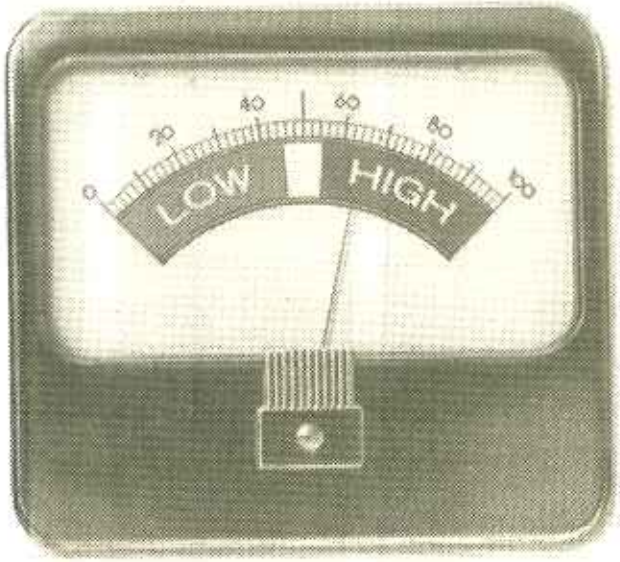
Changes coming but today
No smart P meters
No P savings "Negawatts"
via:
- CFL & LED ← just starting
- Motor Control ← just starting
No smart grid



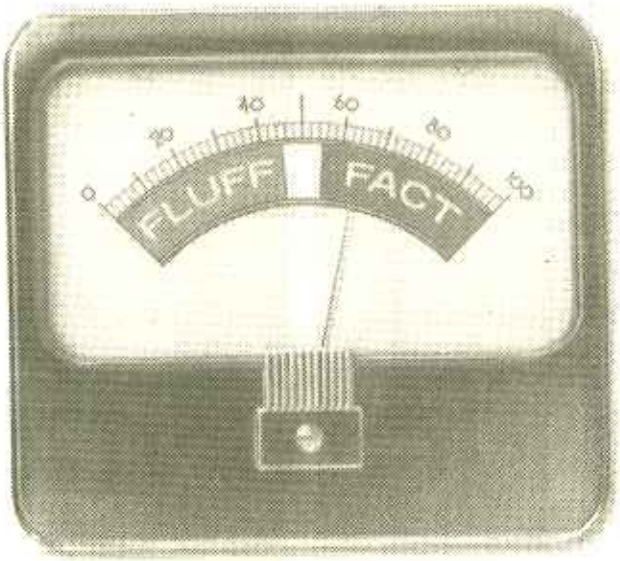
PERFORMANCE



CLARITY

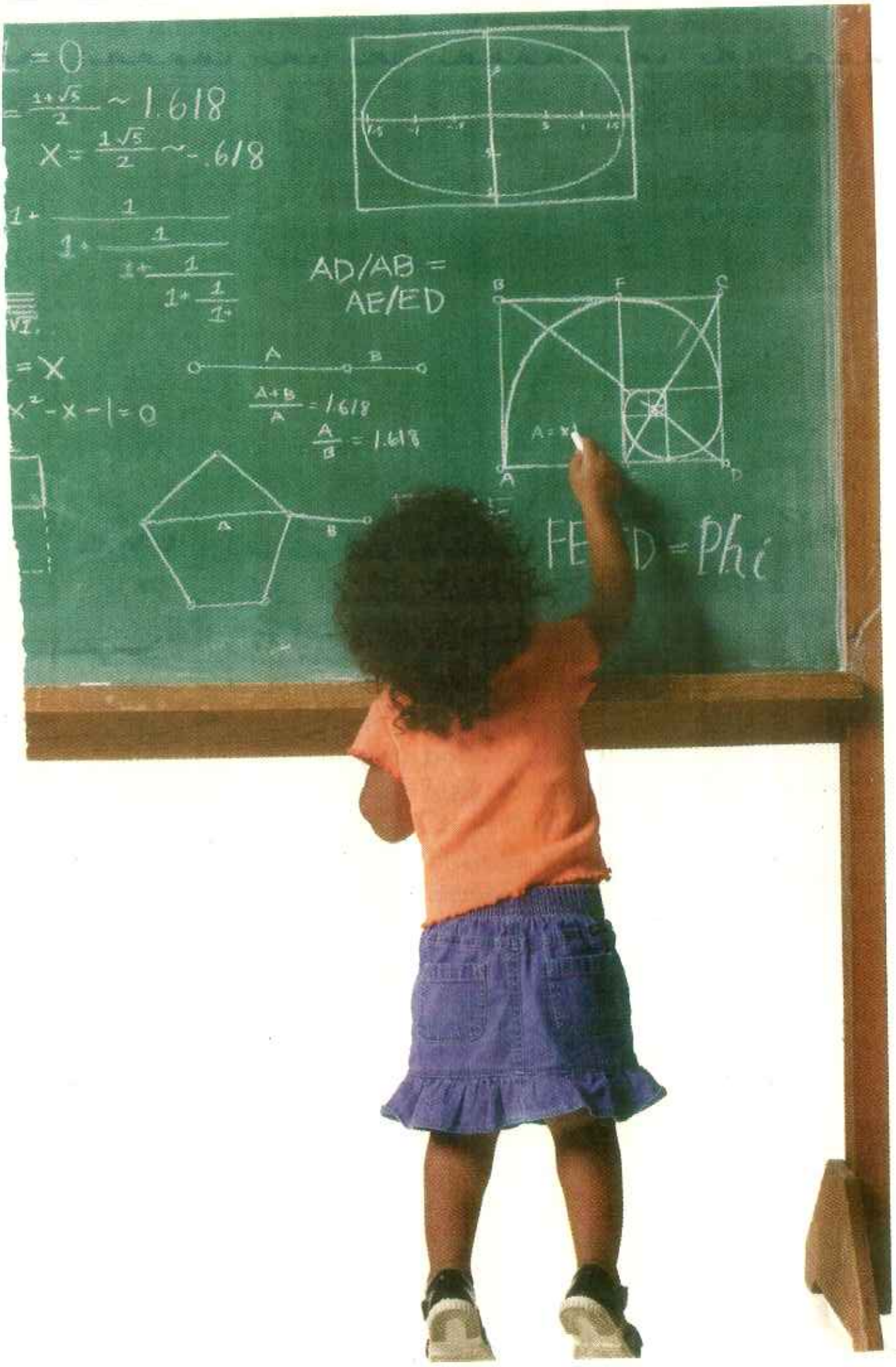


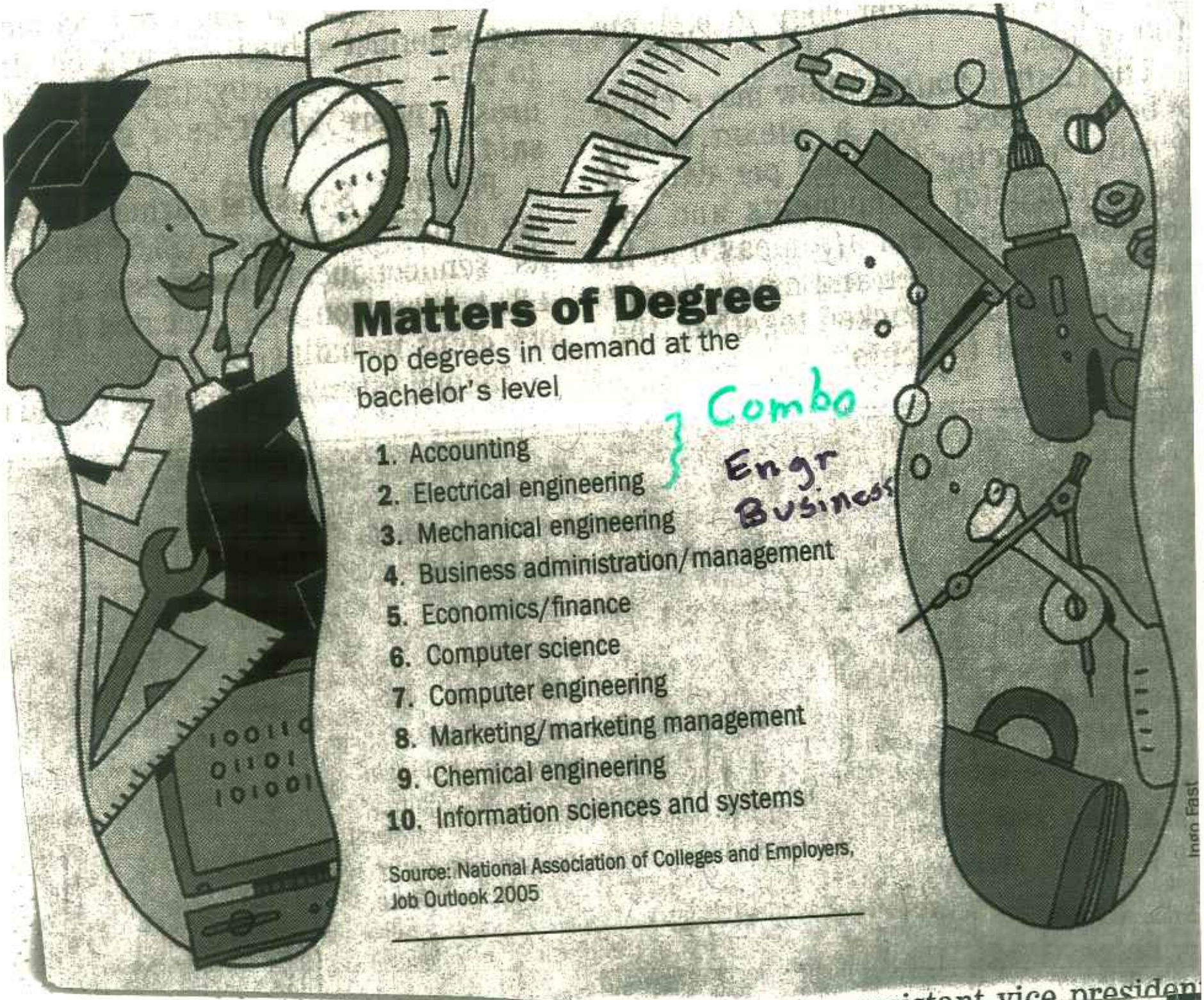
RISK



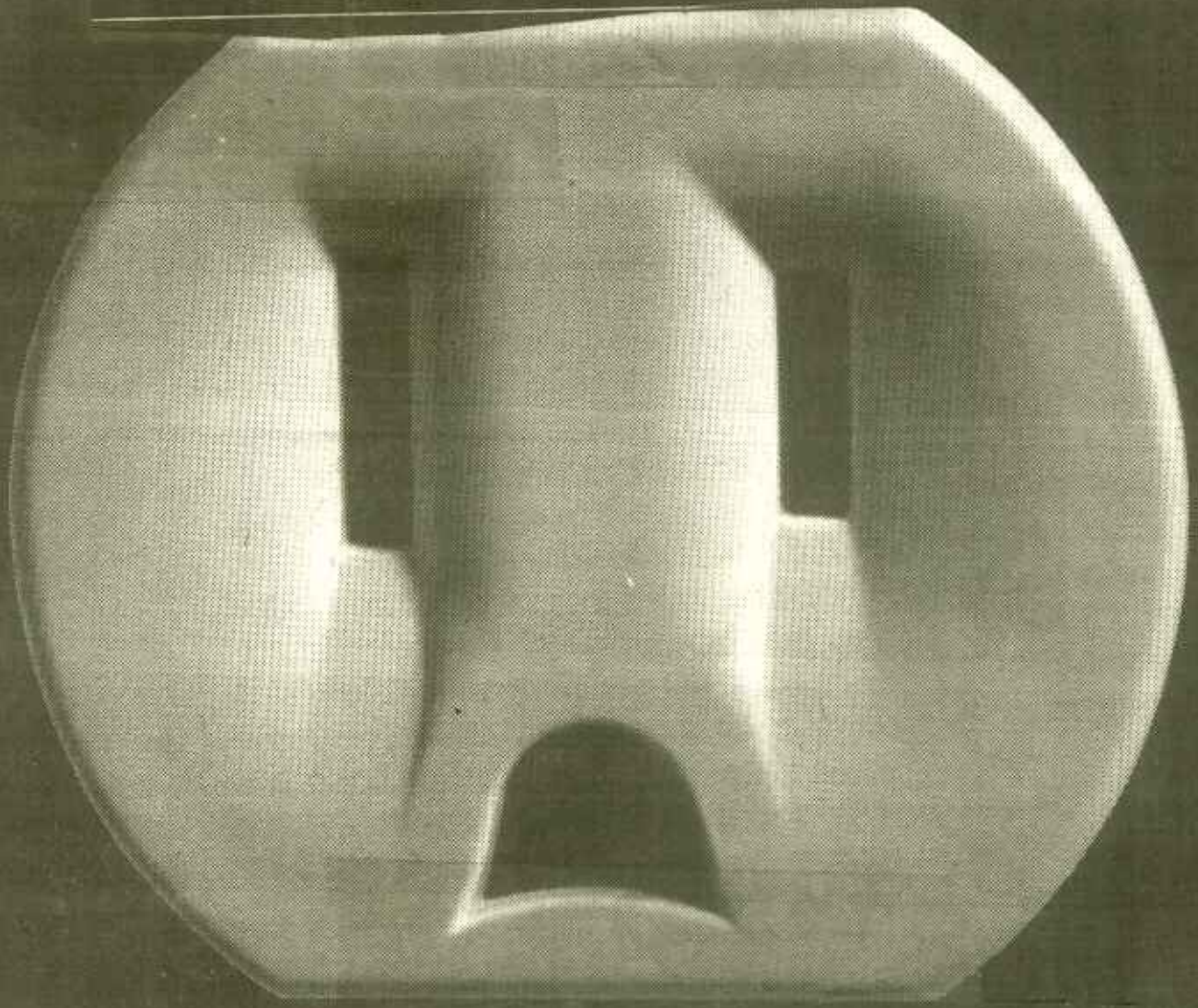
HONESTY

"We've all dozed off during a PowerPoint, Bentham, but today was over the top."


= 0
$\frac{1+\sqrt{5}}{2} \sim 1.618$
$X = \frac{1\sqrt{5}}{2} \sim .618$
$1 + \frac{1}{1 + \frac{1}{1 + \frac{1}{1 + \frac{1}{1+}}}}$
AD/AB =
AE/ED
= X
$x^2 - x - 1 = 0$
A
B
$\frac{A+B}{A} = 1.618$
$\frac{A}{B} = 1.618$
B
F
C
A
D
A = X
A
B
FE D = Phi


Matters of Degree
Top degrees in demand at the bachelor's level
1. Accounting
2. Electrical engineering
3. Mechanical engineering
4. Business administration/management
5. Economics/finance
6. Computer science
7. Computer engineering
8. Marketing/marketing management
9. Chemical engineering
10. Information sciences and systems
Source: National Association of Colleges and Employers, Job Outlook 2005
Combo
Engr
Business

Sad Socket

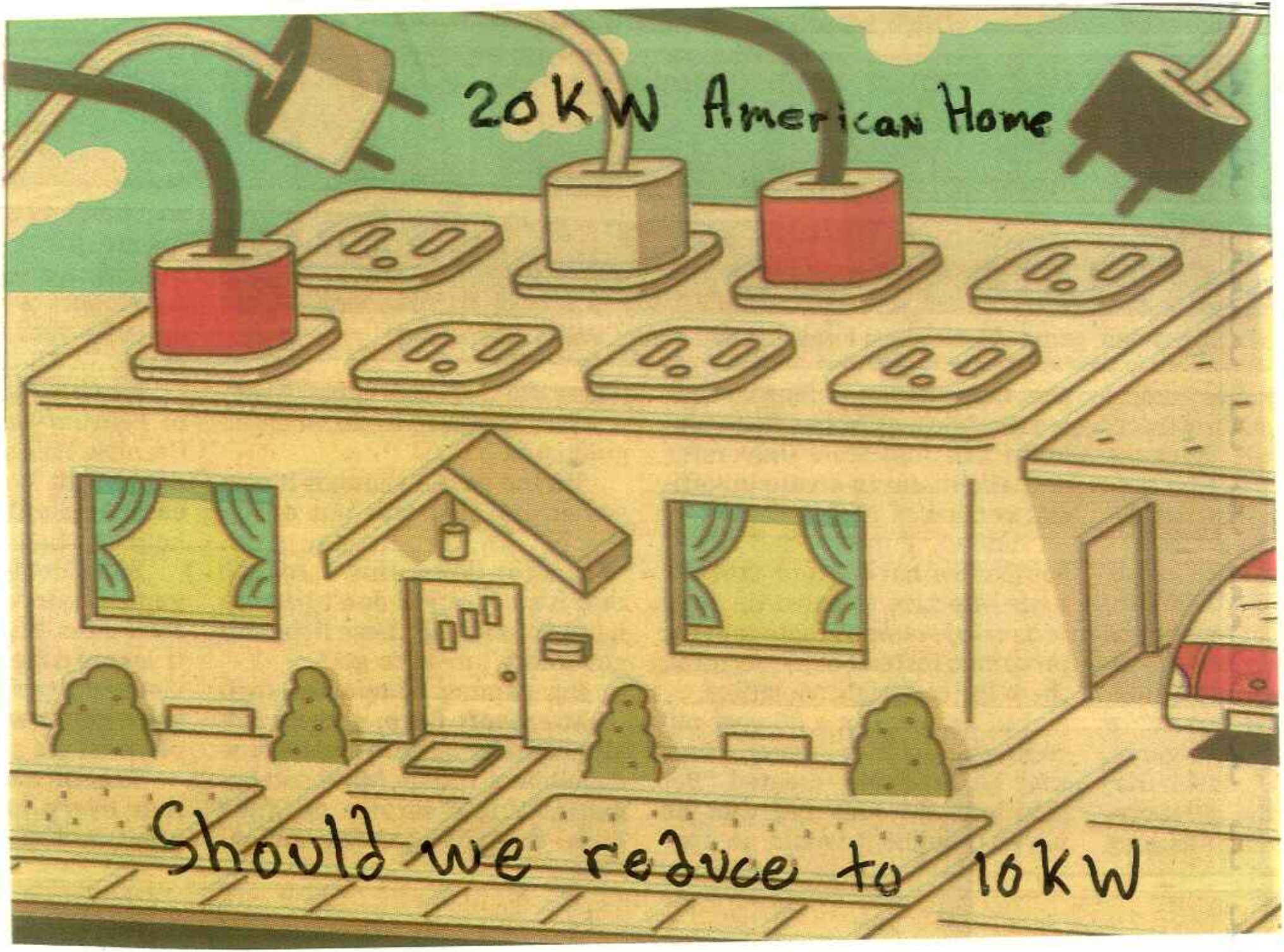


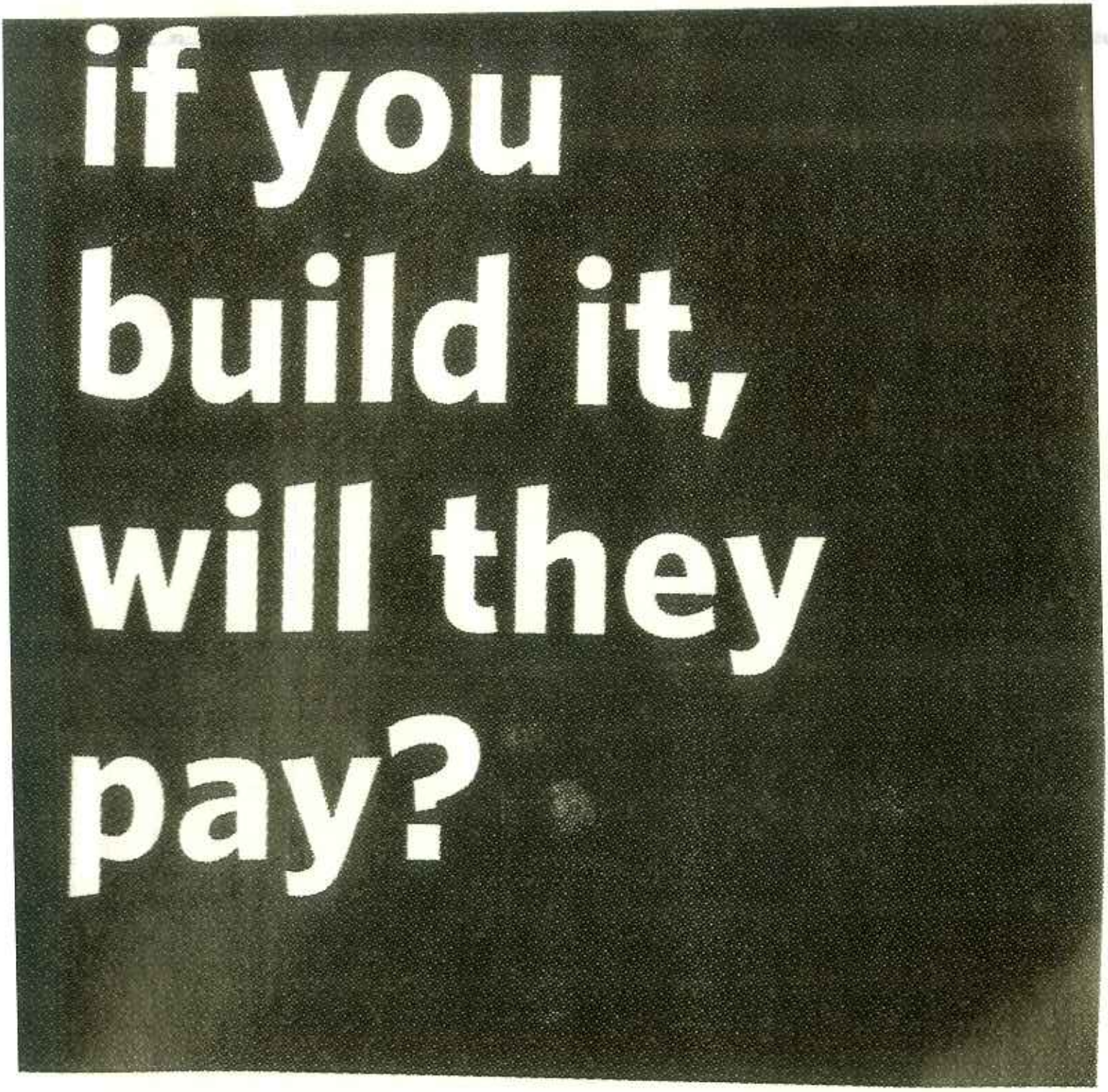
Gets Smart

Smart meters grid

Higher efficiency components

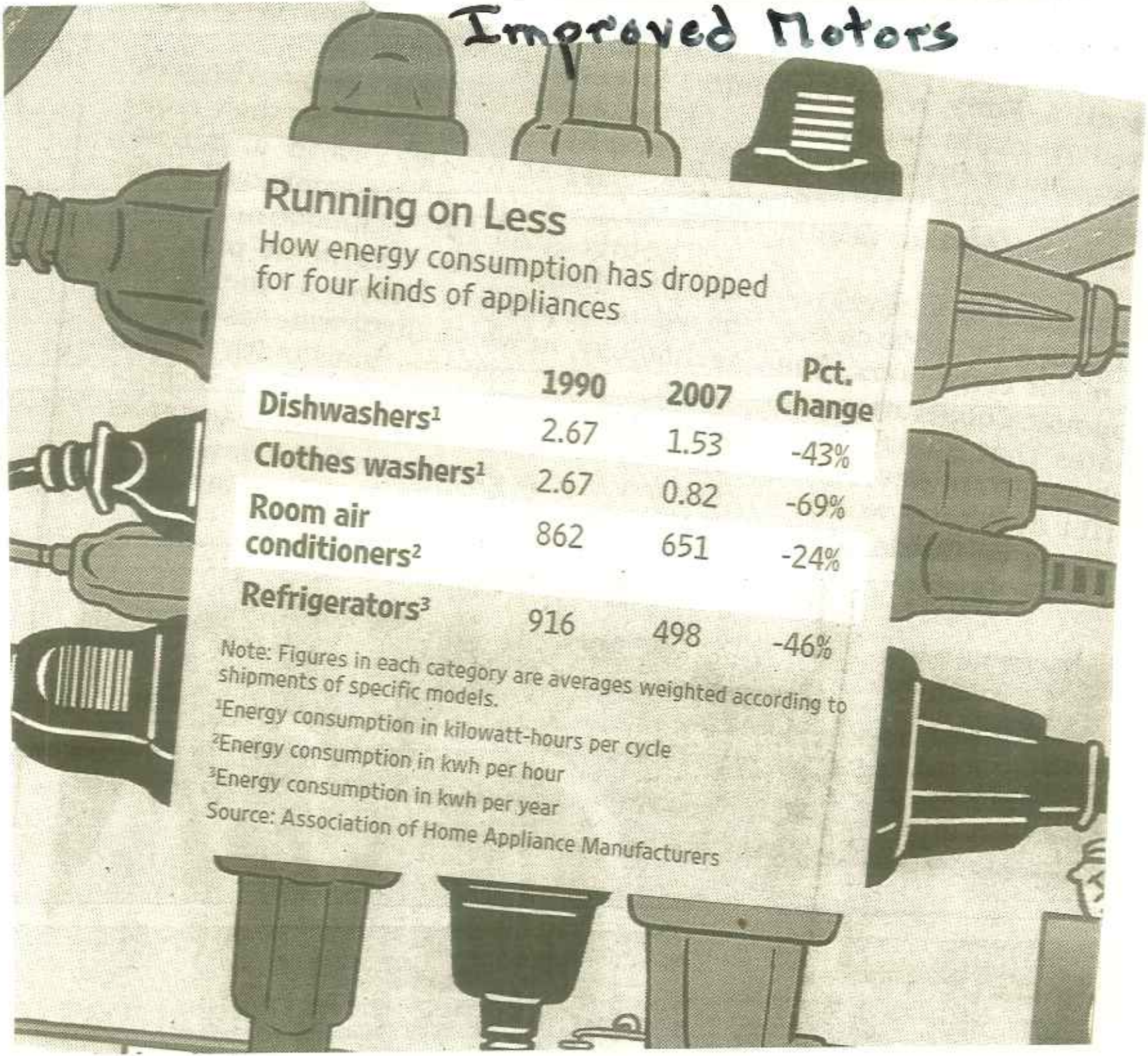
Lower P use by less comfort


20kW American Home
Should we reduce to 10kW



My Generation energy crisis forced conservation by LAW

Improved Motors



Running on Less

How energy consumption has dropped for four kinds of appliances

	1990	2007	Pct. Change
Dishwashers[1]	2.67	1.53	-43%
Clothes washers[1]	2.67	0.82	-69%
Room air conditioners[2]	862	651	-24%
Refrigerators[3]	916	498	-46%

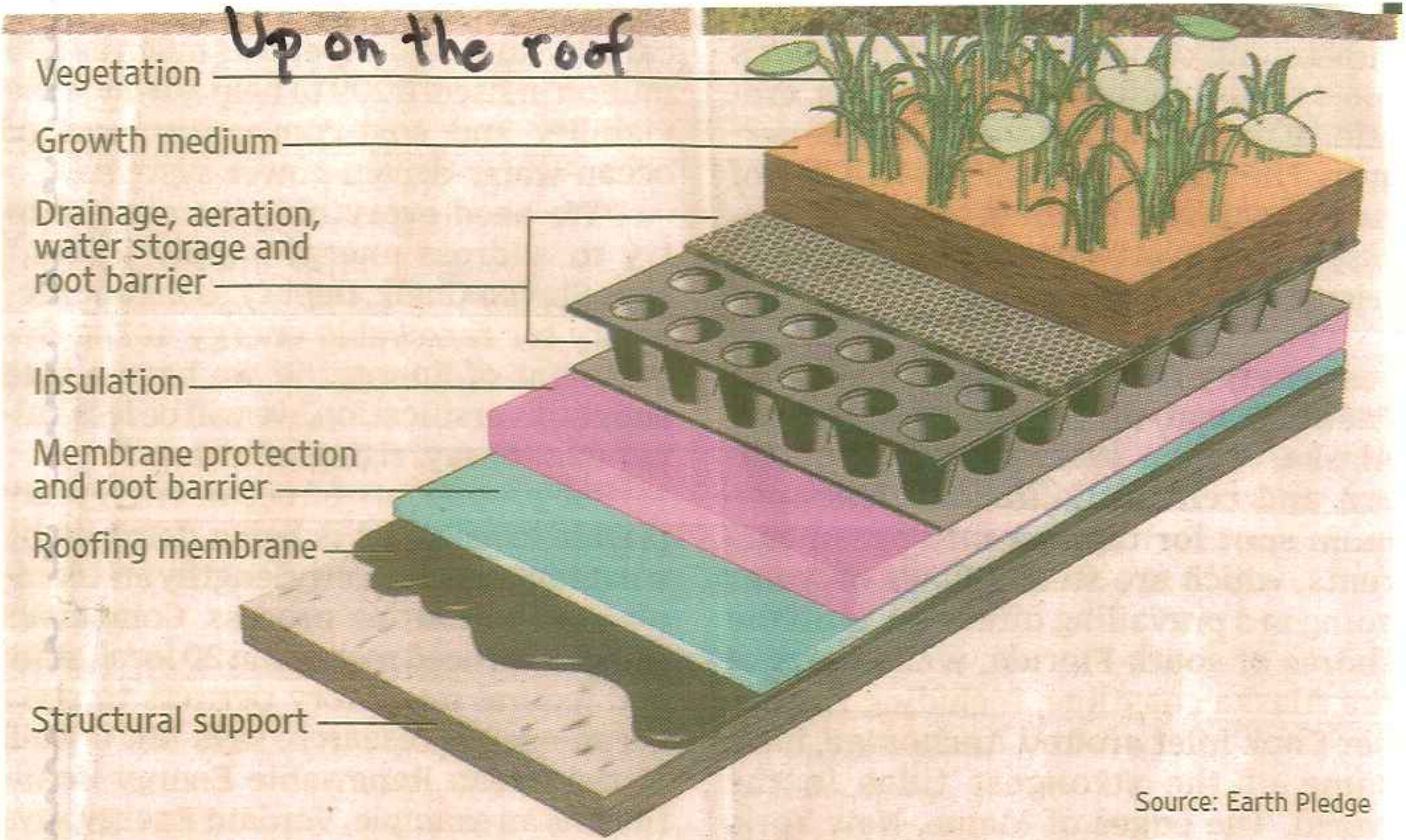
Note: Figures in each category are averages weighted according to shipments of specific models.

[1]Energy consumption in kilowatt-hours per cycle

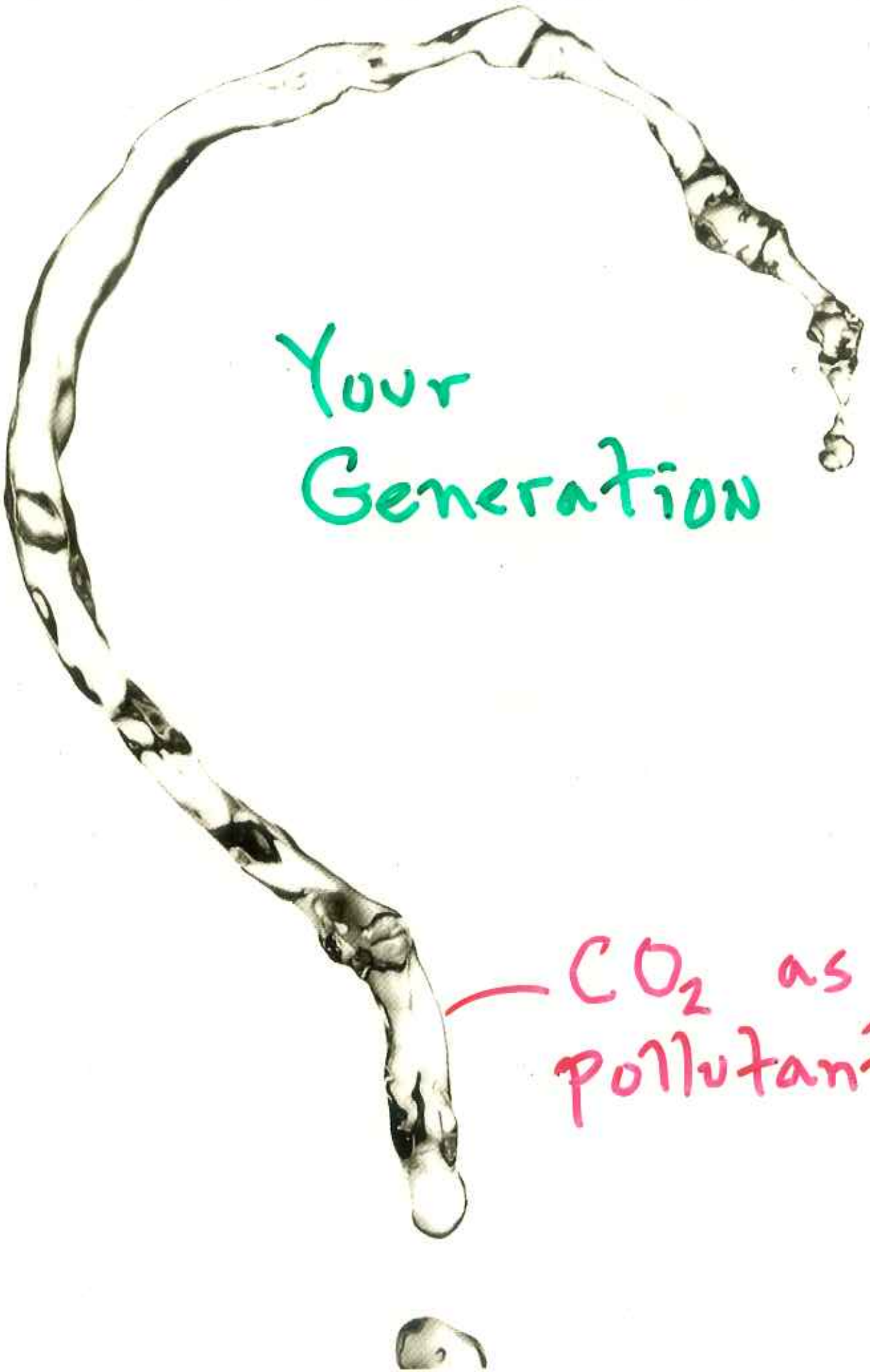
[2]Energy consumption in kwh per hour

[3]Energy consumption in kwh per year

Source: Association of Home Appliance Manufacturers

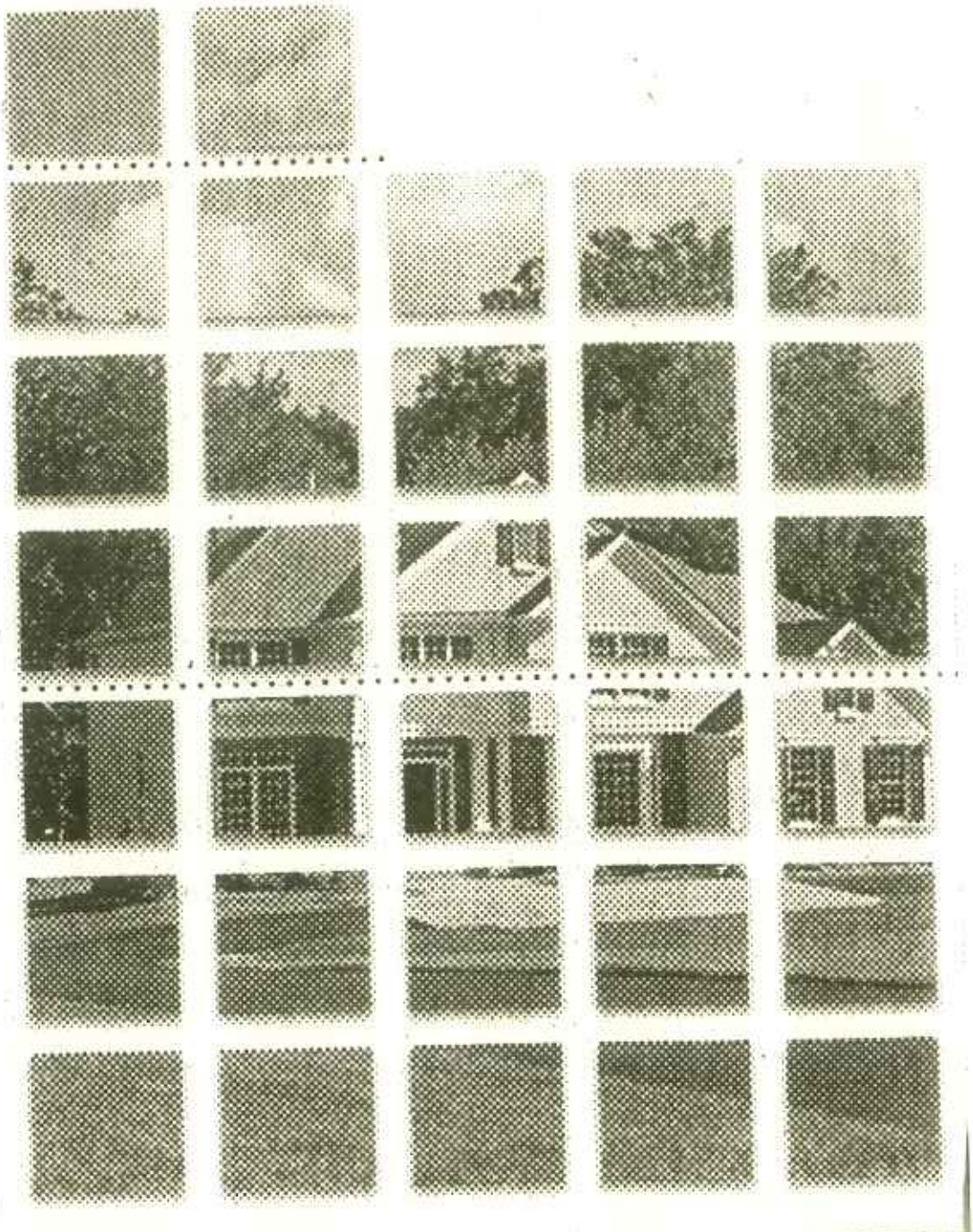


TOP GROWTH *Green roofs on residential (left) and commercial (right) buildings in Kansas City, Mo.; the layers of one kind of green roof system*


Your
Generation
— CO_2 as a
pollutant?

Sources of emissions unde consumers' direct contro

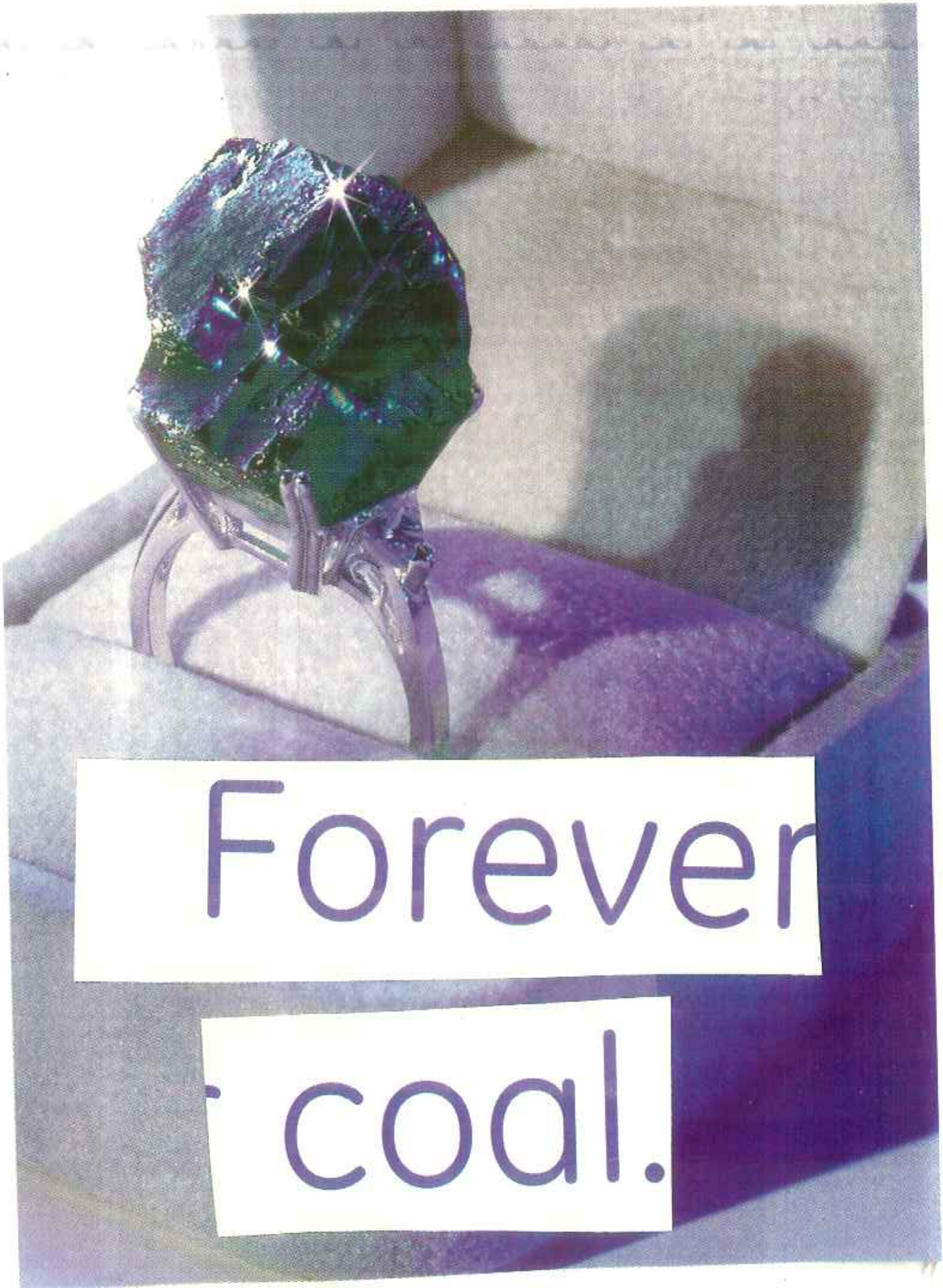
37%



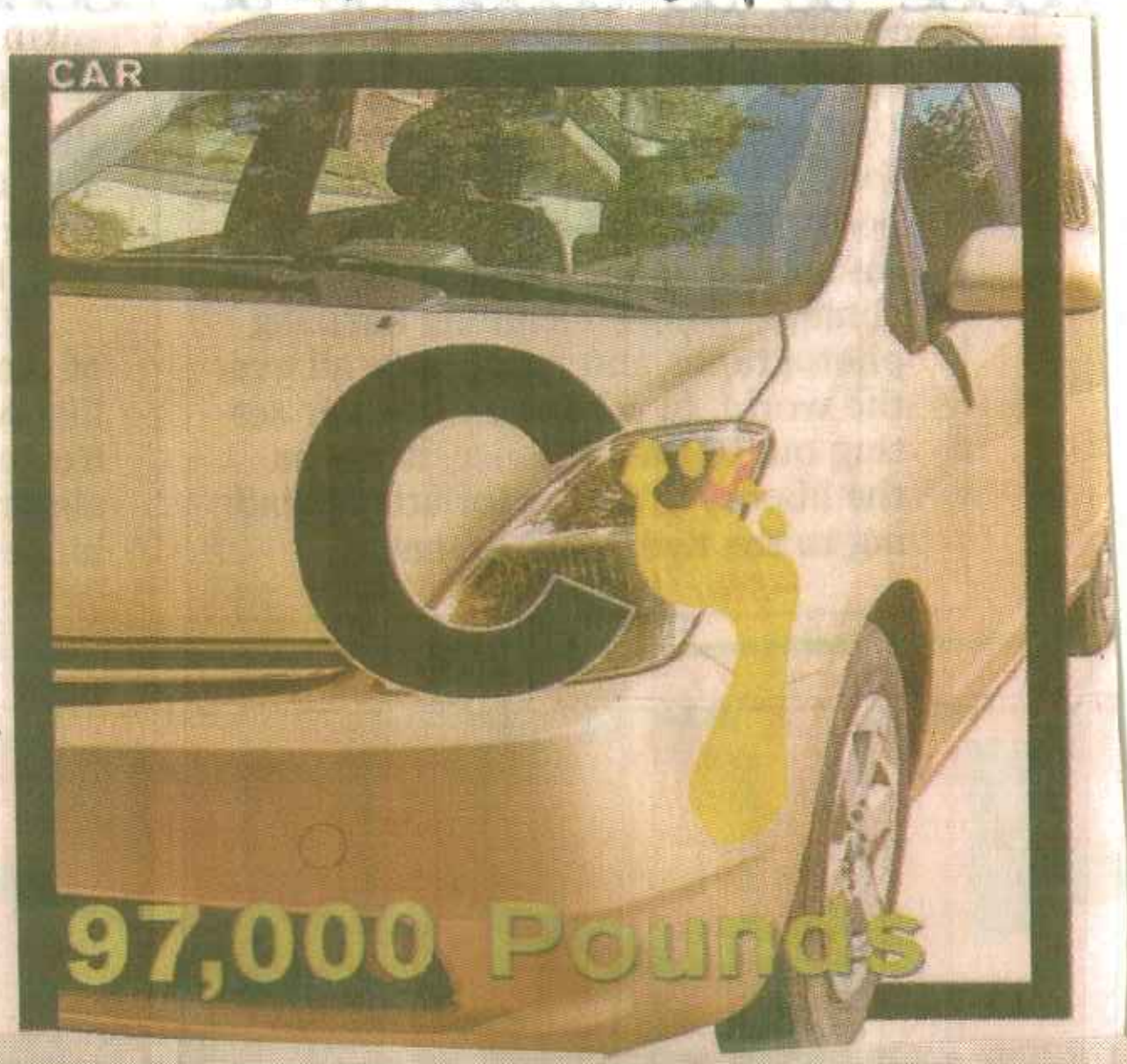
Passenger air travel, **2%**

Passenger cars **17%**

Residential buildings and appliances* **17%**

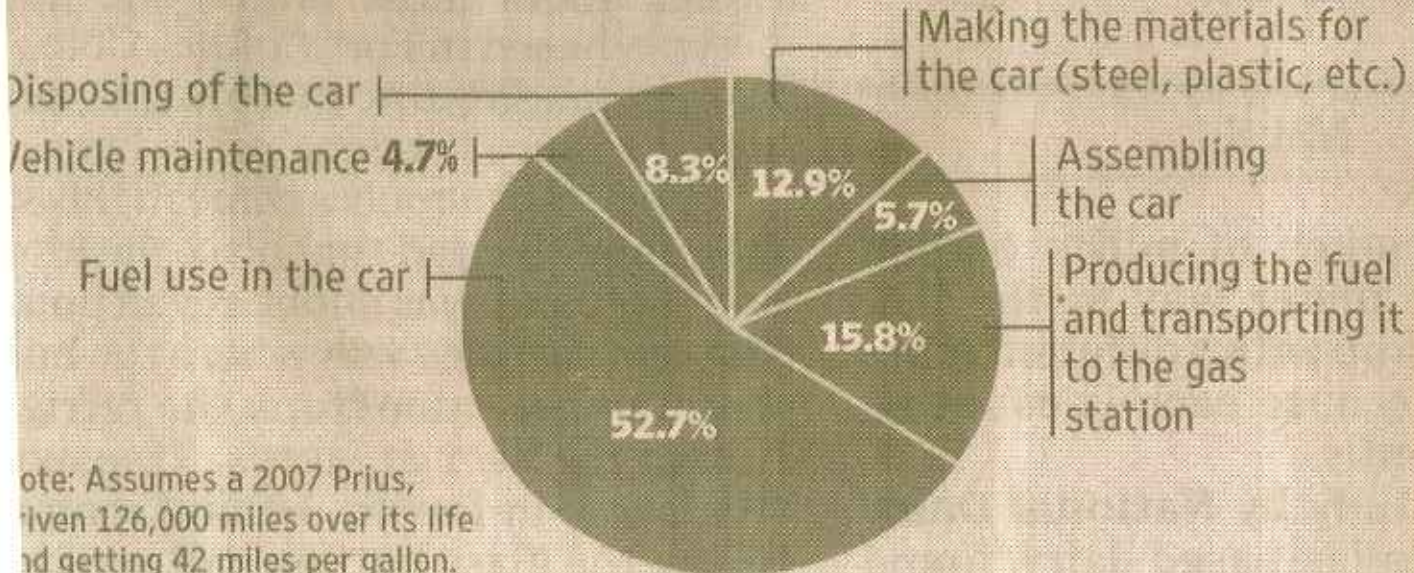

Forever
coal.

Carbon Footprints



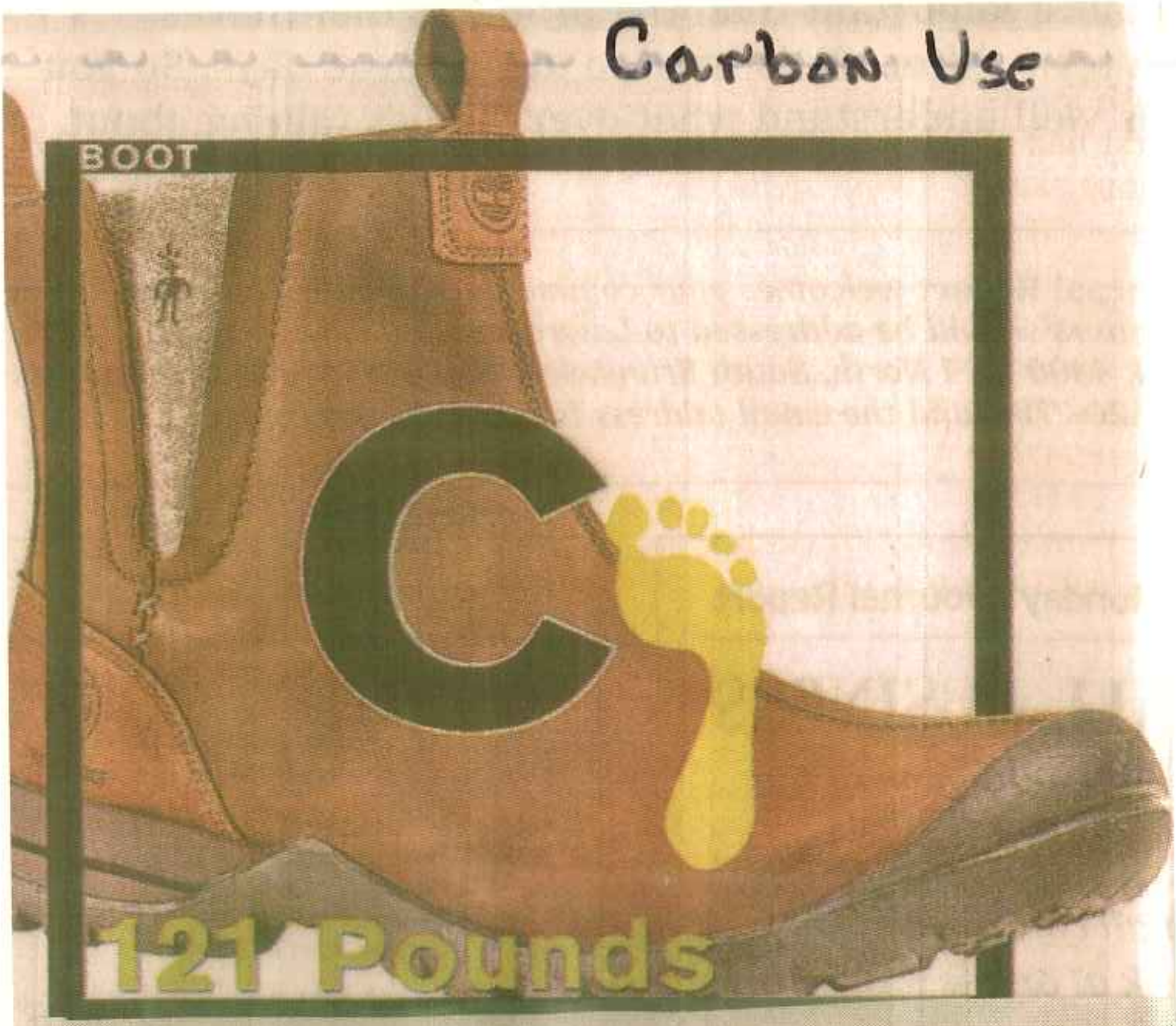
CAR Toyota Prius

TOTAL FOOTPRINT: **97,000 pounds**



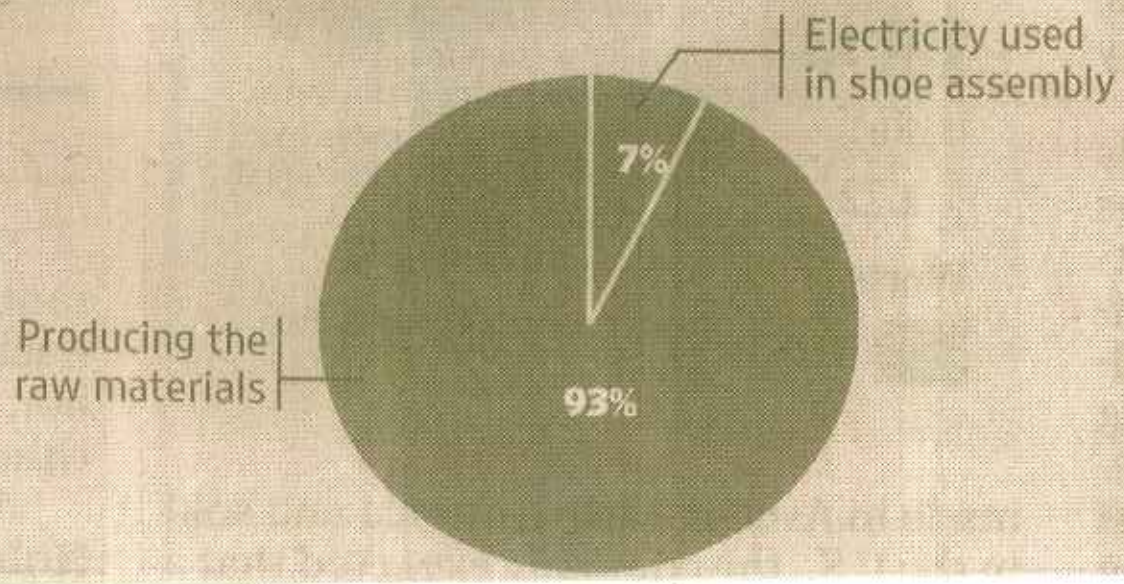
Note: Assumes a 2007 Prius, driven 126,000 miles over its life and getting 42 miles per gallon.

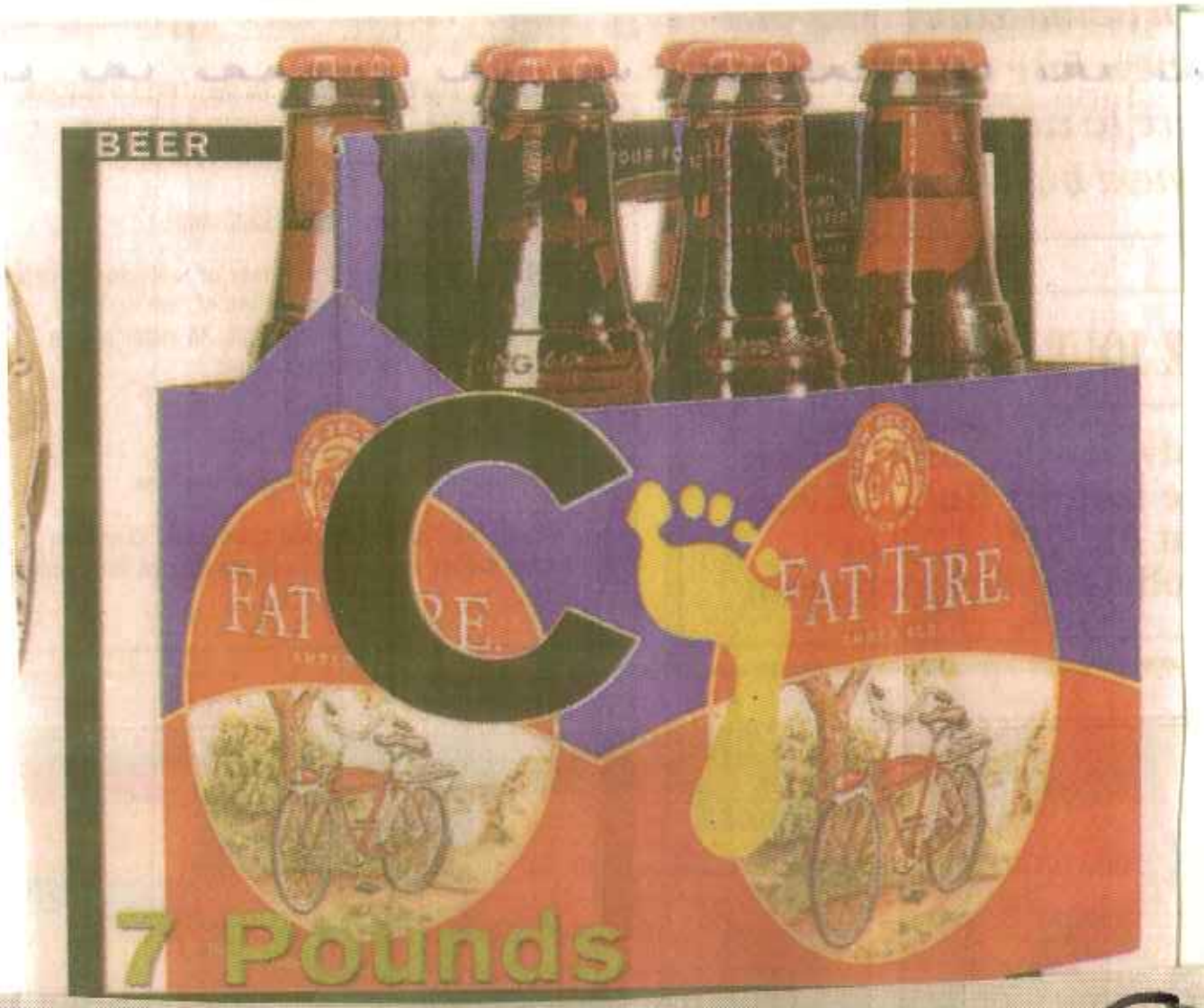
Carbon Use



PAIR OF HIKING BOOTS **Timberland Winter Park Slip On Boots**

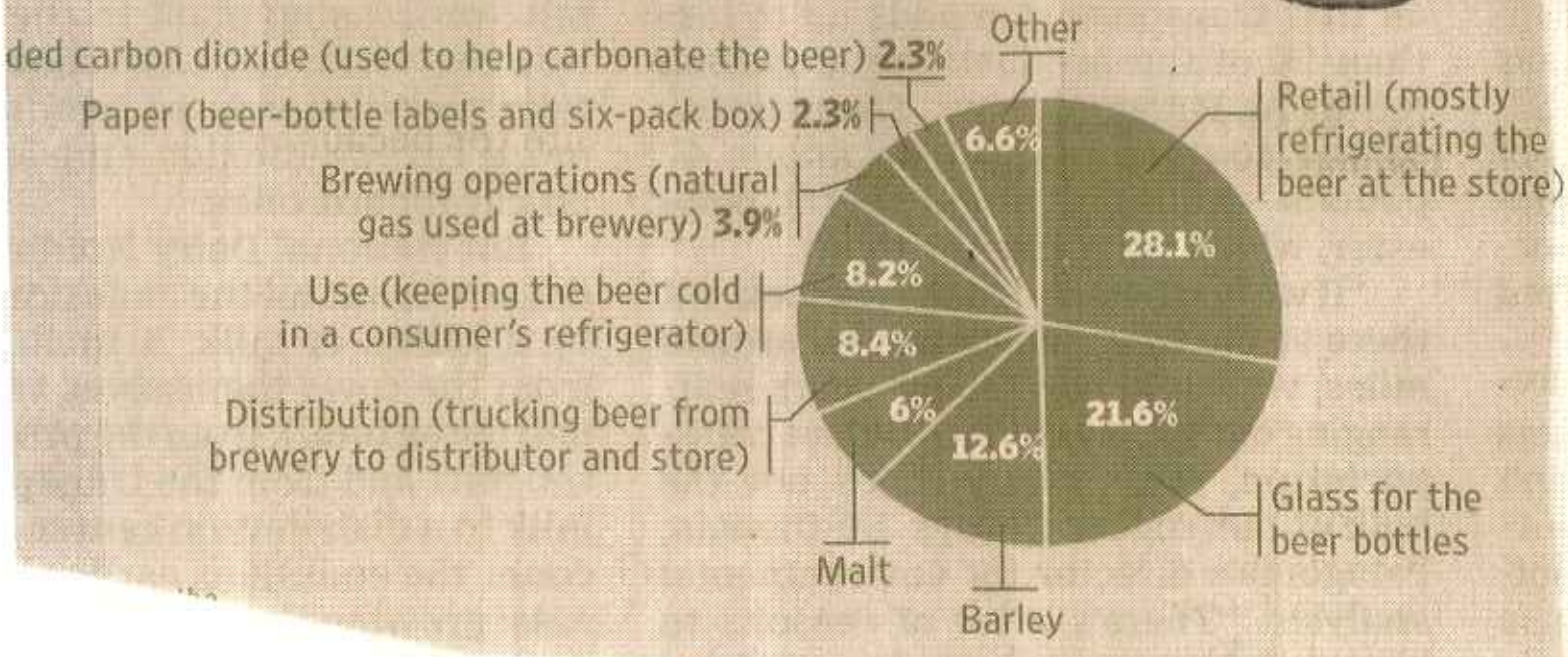
TOTAL FOOTPRINT: **121 pounds**





SIX-PACK OF BEER **Fat Tire Amber Ale**

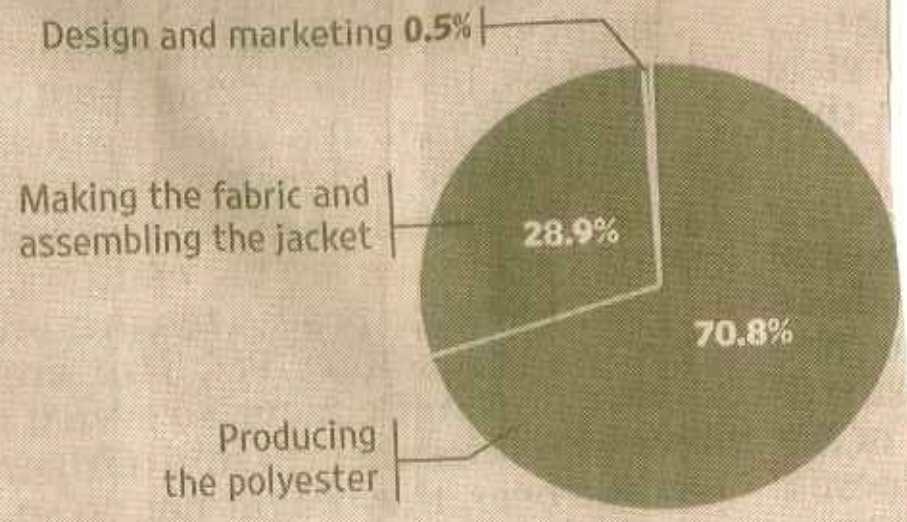
TOTAL FOOTPRINT: **7 pounds**



Carbon Generation

FLEECE JACKET Patagonia Talus jacket

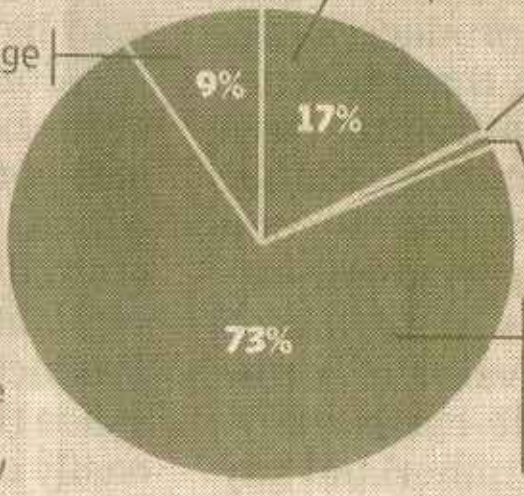
TOTAL FOOTPRINT: **66 pounds**[1]



[1]Includes emissions from producing the oil that's used to make the pol
jacket's arrival at Patagonia's distribution center in Reno, Nev. Doesn't
from the distribution center to retail stores, which Patagonia says is ne

LAUNDRY DETERGENT Tesco Non-Biological Liquid Wash

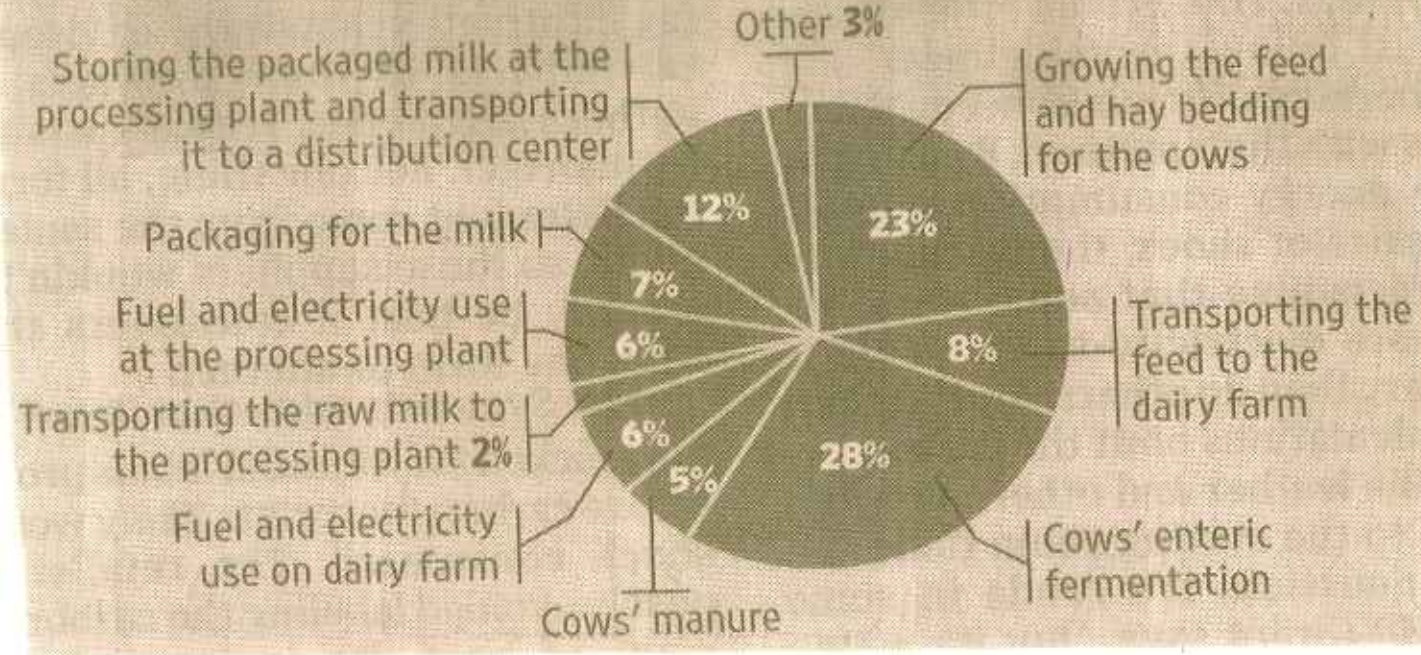
TOTAL FOOTPRINT: **31 pounds**

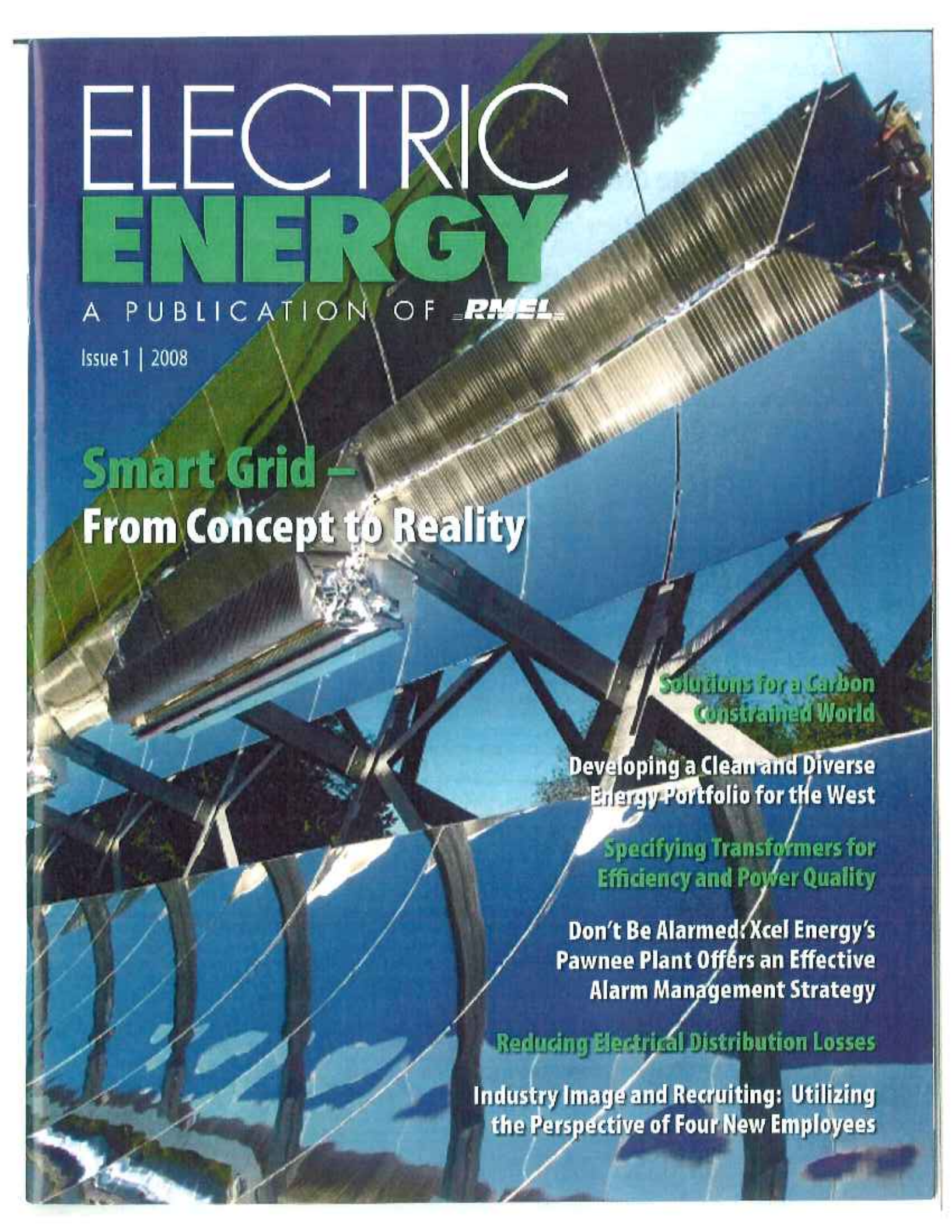


Note: Based on a 1.5-liter bottle (about 1.5 quarts), 20 loads per bottle and 9.9 pounds of laundry per load.

HALF-GALLON OF MILK Aurora Organic Dairy

TOTAL FOOTPRINT: **7.2 pounds**[2]





ELECTRIC ENERGY

A PUBLICATION OF PMEL

Issue 1 | 2008

Smart Grid – From Concept to Reality

Solutions for a Carbon Constrained World

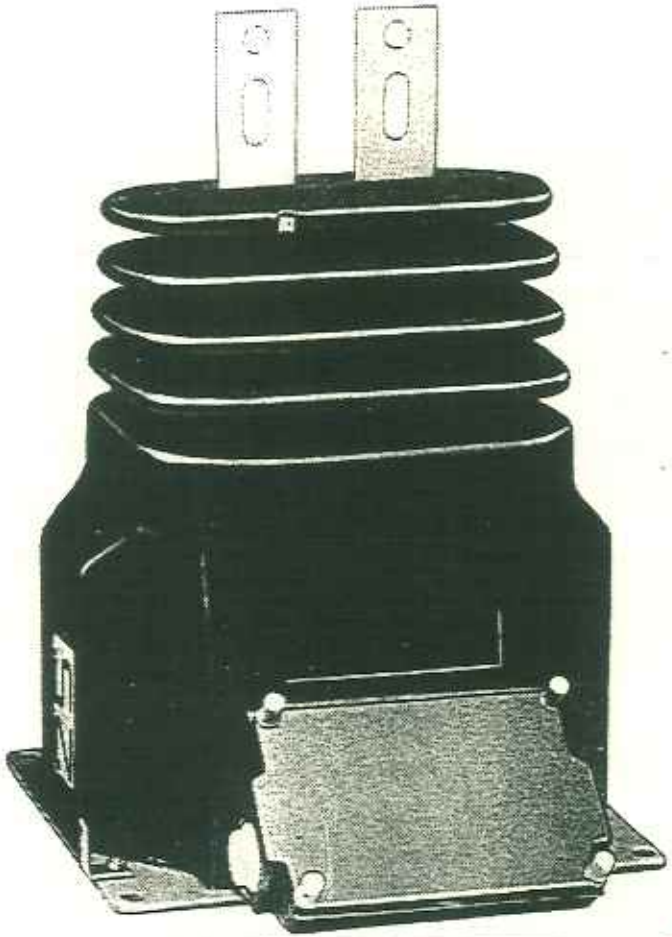
Developing a Clean and Diverse Energy Portfolio for the West

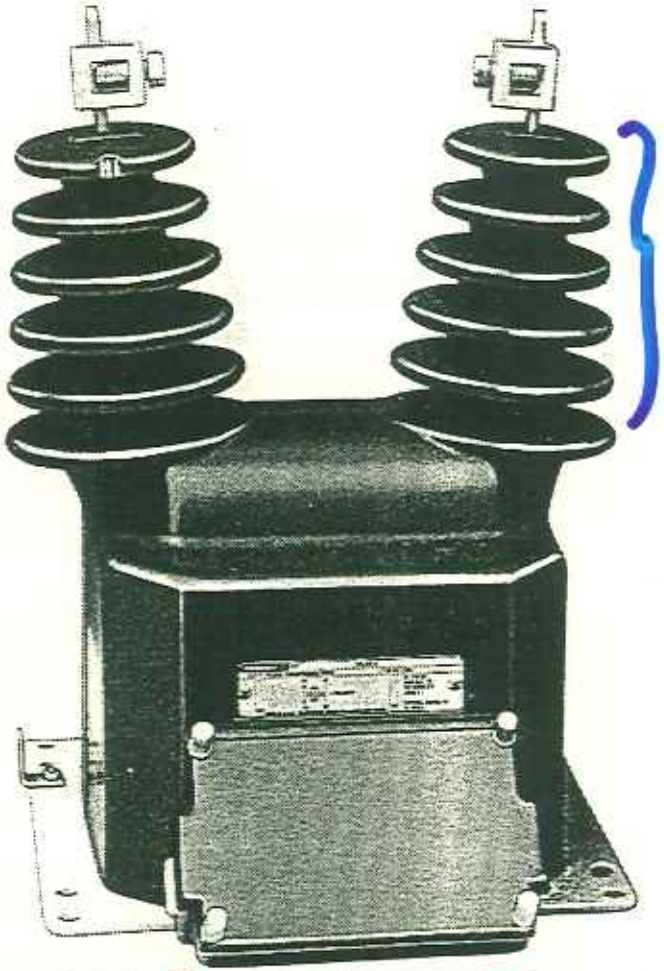
Specifying Transformers for Efficiency and Power Quality

Don't Be Alarmed: Xcel Energy's Pawnee Plant Offers an Effective Alarm Management Strategy

Reducing Electrical Distribution Losses

Industry Image and Recruiting: Utilizing the Perspective of Four New Employees





?

HV transformed to a low V

V_{ll}, I_l

Instrument Transformers

Why stray C a worry?

Instrument / Measuring Trfs

B

Voltage Trf

V_{IN} → 115

Any i? draw

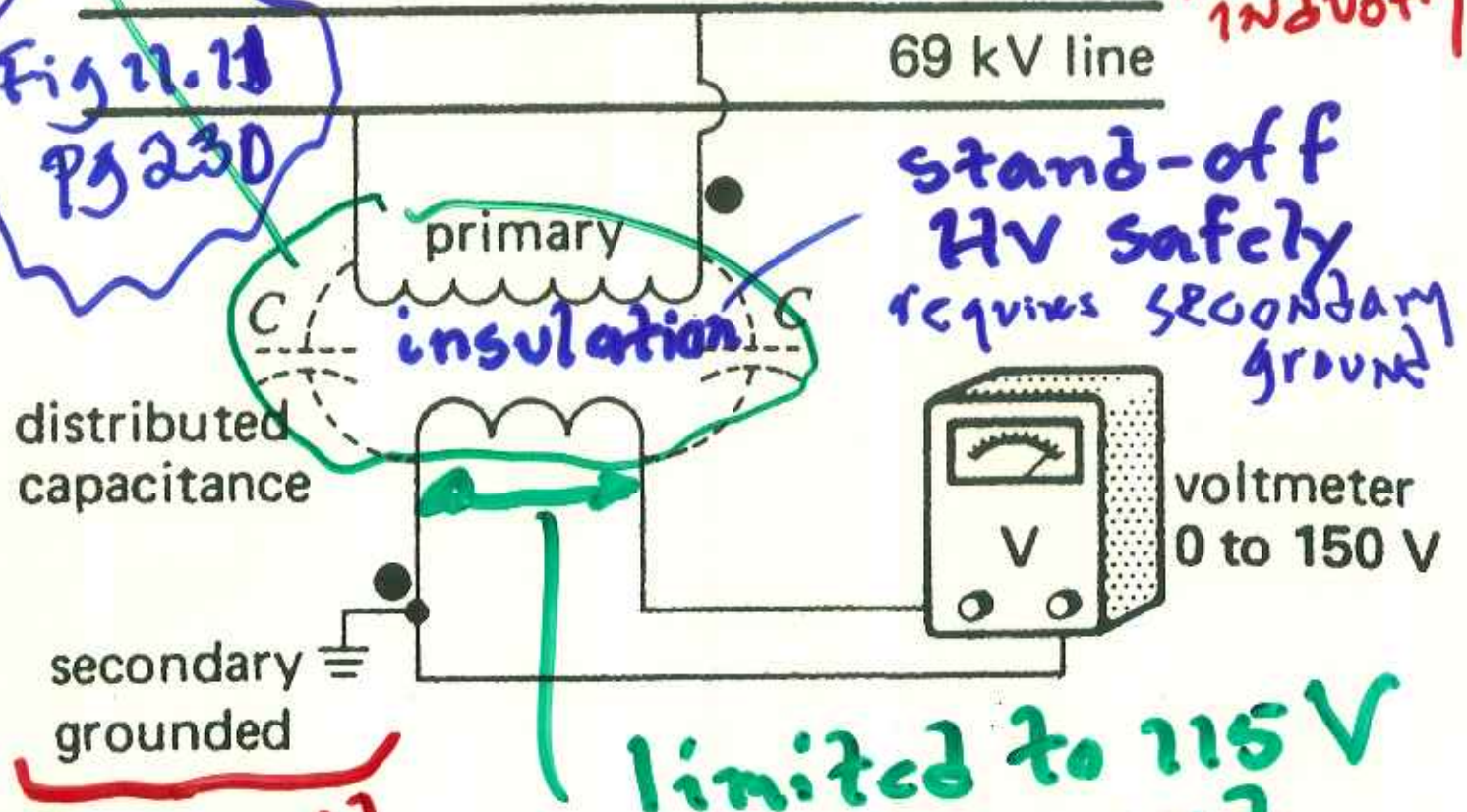
① V_{IN} any HV

V_{out} 115 V full scale

Power Std: $Z_{out} = \infty$

Std in power industry

Fig 11.11 pg 230



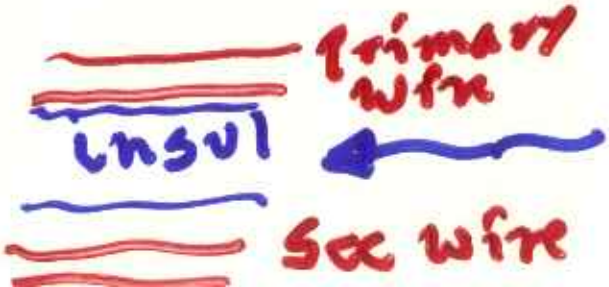
stand-off HV safely requires secondary ground

limited to 115 V via ground

② To avoid shock by "parasitic" C

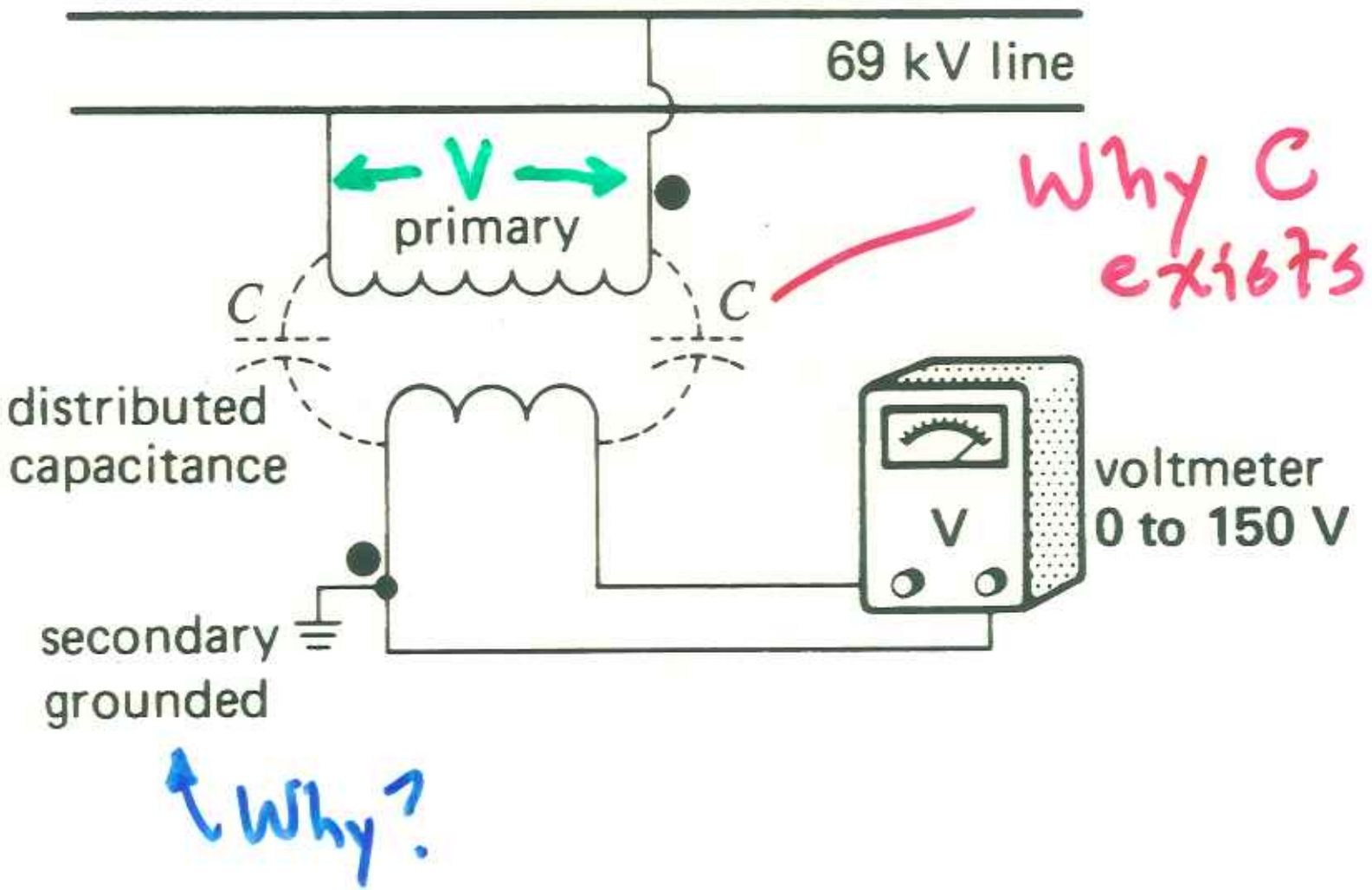
14.4 kV 115 } full scale

69 kV 115



most of trf is insulation

Figure 11-11 Potential transformer installed on a 69 kV line. Note the distributed capacitance between the windings.



Theodore Wildi
Electrical Machines, Drives, and Power Systems, 5e

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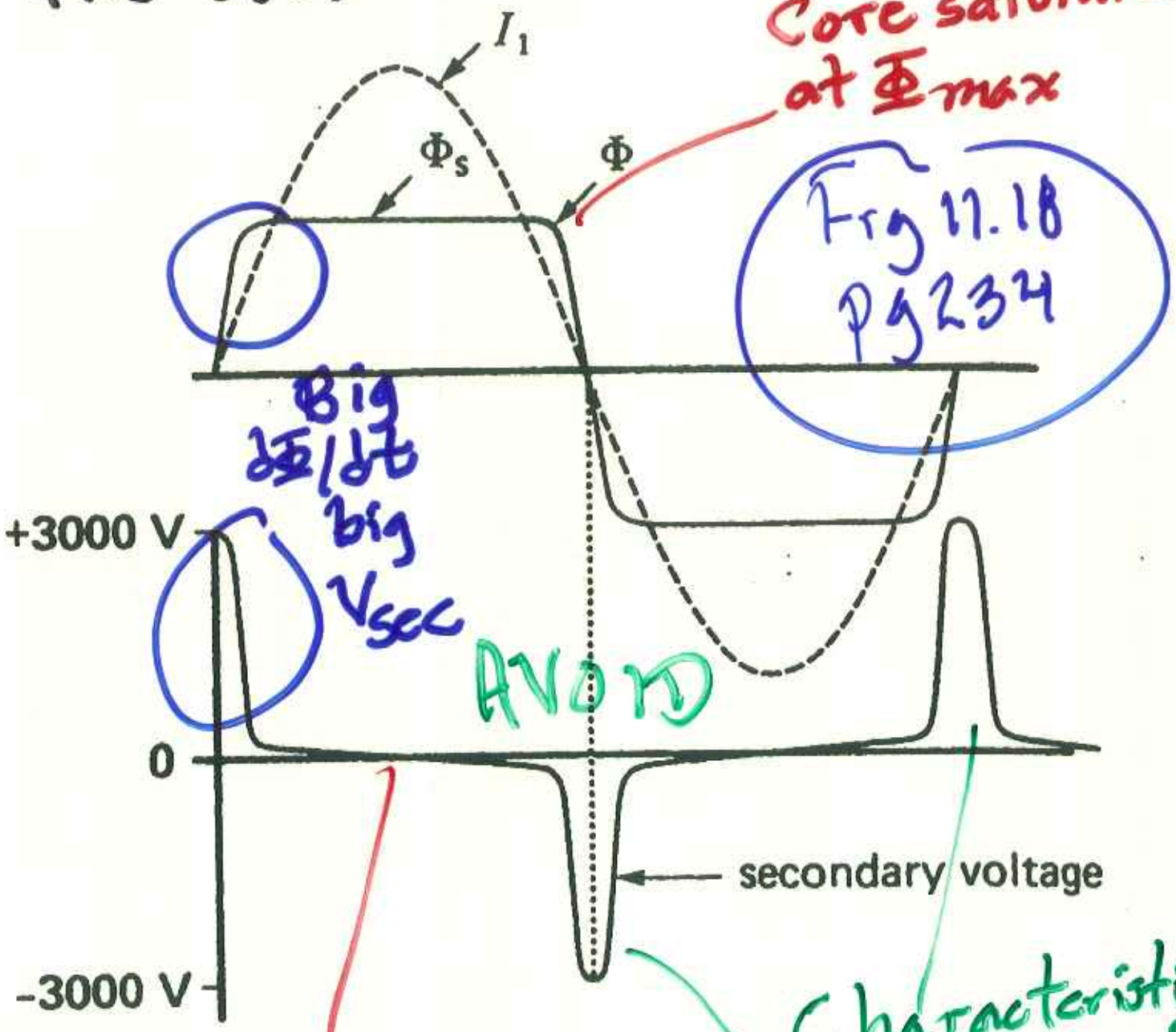
18

CT with Z_L large (should be $\to 0$)

Open circuit secondary on CT is dangerous. It also distorts the i(t) waveform



Core saturates at Φ_{max}

Fig 17.18 pg 234

Big $d\Phi/dt$ big V_{sec}

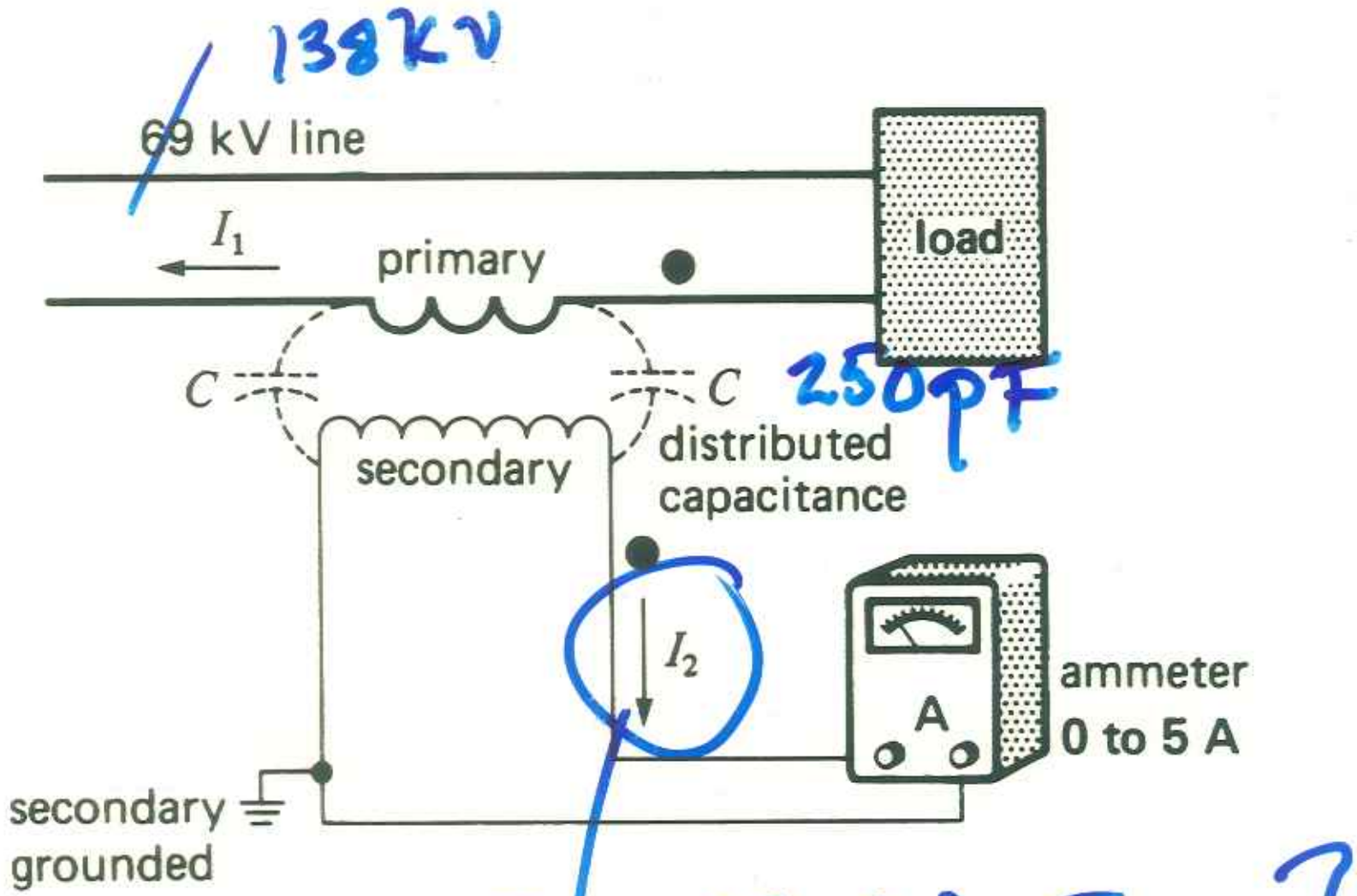
AVOID

$$V_{sec} = \frac{d\Phi}{dt} = 0$$

Characteristic V_{out} signal for saturated CT = N.G.

i trf issues

Figure 11-13 Current transformer installed on a 69 kV line.



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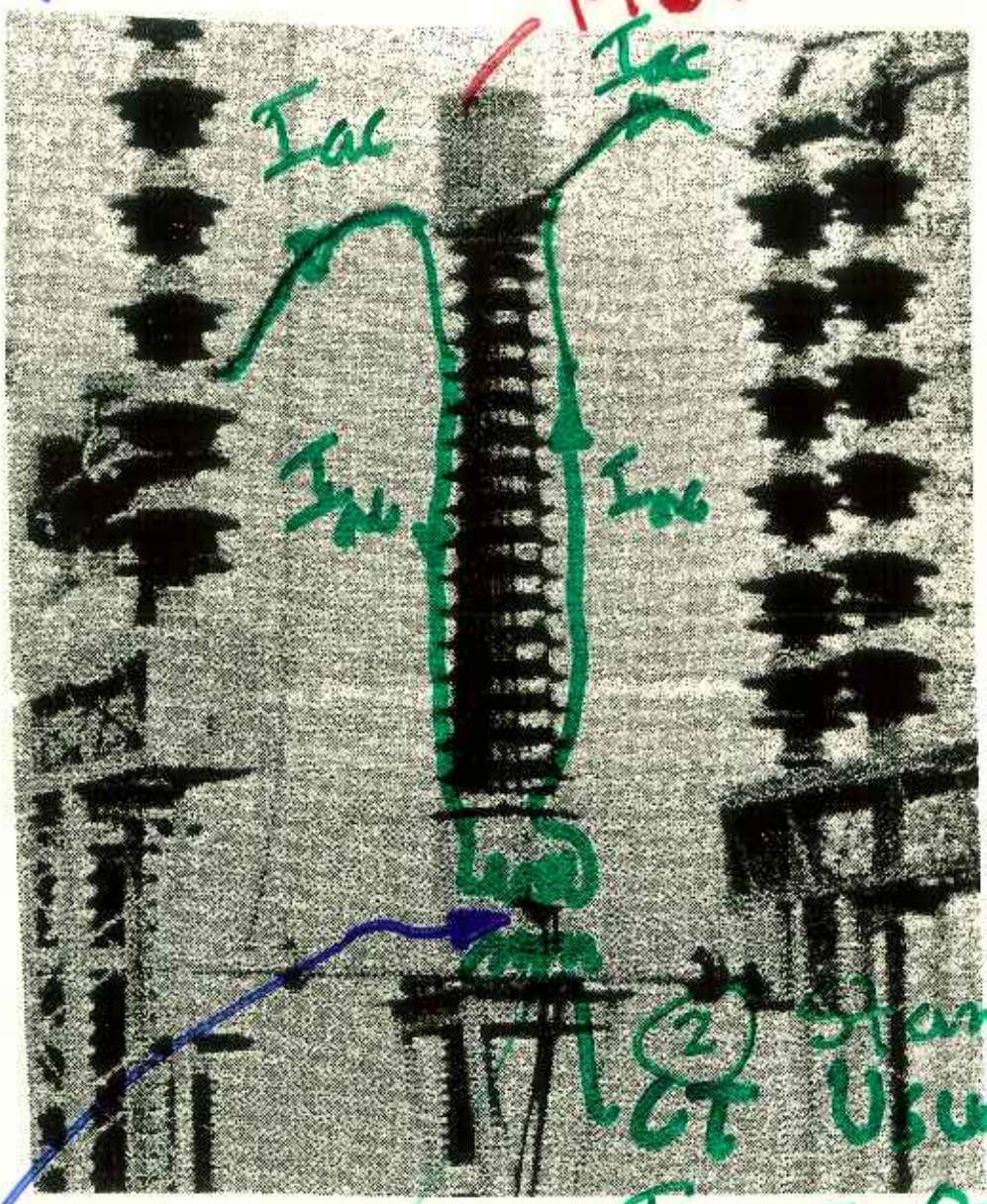
Current Trf (for i on HV line)

Fig 11.16
Pg 233

① crackly 220 kV AC } want to safely measure

MOV

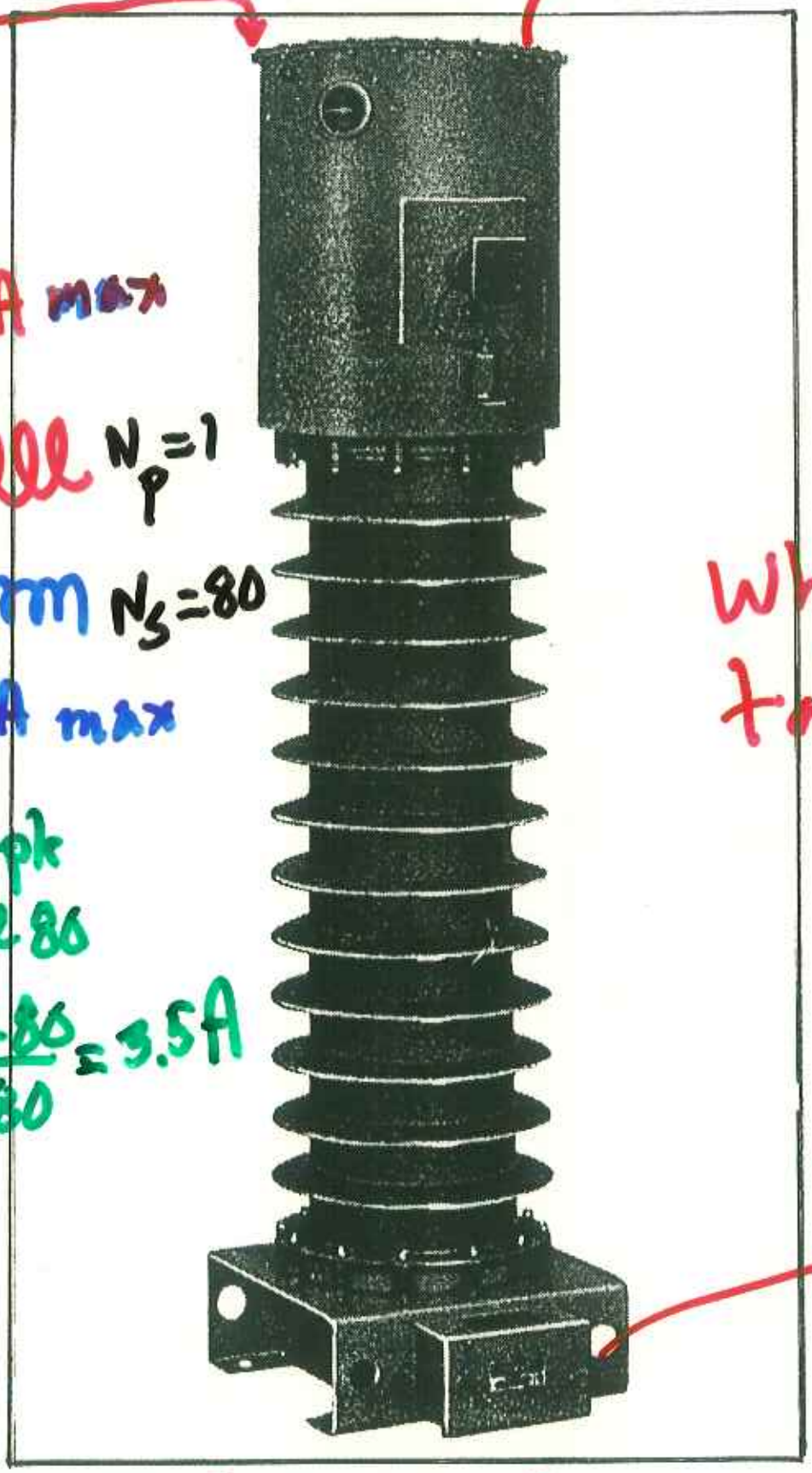


② Standard CT Usually

$I_{out} = 0\text{-}5A$ full scale

Mostly insulation

③ $S_{CT} = I_p V_p = I_s V_s$



Is there other ways to insulate / isolate

LineTracker

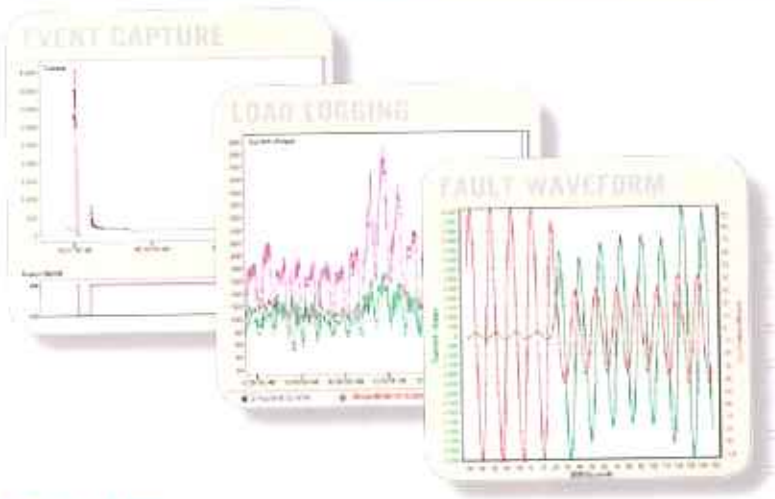
Intelligent Grid Monitoring

Distribution Load Logger
& Fault Recorder

LT40

- Distribution Monitoring
- Substation Monitoring
- Fault Finding
- Line Balancing
- Capacity Planning

The LT40 System offers cost effective, real-time wireless Smart Grid monitoring of overhead distribution circuits up to 69KV. Critical line condition and performance parameters, including Fault, Protection Operation, Outage, Restoration and Loading are captured providing the data needed to optimize asset utilization and to improve system reliability and quality of supply.



Features

- ☑ Up to 69KV
- ☑ Live Installation
- ☑ Wireless
- ☑ Self-Powered
- ☑ Easy to use

GridSense™

T&D Solutions Since 1974

LineTracker LT40

Intelligent Grid Monitoring

The LineTracker series of overhead line recorders are the most versatile, powerful and the only self-powered intelligent devices available to Power Utilities. The LineTracker provides accurate information on the performance and condition of the lines allowing utilities to quickly respond to failing equipment, over-loading conditions and reliability issues.

LineTracker recorders can be quickly installed on live lines at any point on the overhead distribution system (e.g. substation busbar, beyond non-intelligent reclosers, switches, risers, taps, midpoints etc.) to measure and record **critical load, fault** and **operational parameters.**

With the LineTrackers built-in **wireless communications**, utilities can wirelessly download data onsite or remotely without removing the recorders from the line or waiting for available line crews. The solar cell and battery power system provides the means for **long term monitoring** without the risk of battery failure, high maintenance costs or lost data.

The LineTracker System is a proven, smart and versatile monitoring solution for Power Utilities and is used daily by **System Planners, Distribution Engineers, Troubleshooters,** and **Protection** and **Substation Engineers.**

Sensing & Detection

The LT40 Current and E-field sensors continuously monitor and adapt to line conditions. A hierarchy of algorithms is used to capture data when a Fault, Power-Loss or Power-Return occurs. Upon event trigger, a 60 sec RMS and 12-Cycle Waveform snapshot are captured and recorded to memory. Visual fault indication is provided for patrolling line crews. In parallel to event recording, the LT40 also functions as a distribution load logger.

Wireless Communications

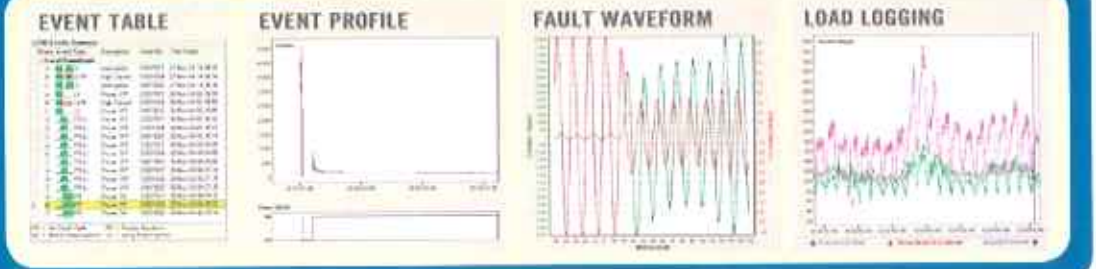
The LineTracker uses license-free radio communications for wireless link up. The LT-DataLink reader is connected to a laptop and, with the software, the user can retrieve data within 150ft of the LineTracker without the need or expense of scheduling a line crew or bucket truck. Utilizing flash memory firmware the LineTracker can also be upgraded wirelessly whenever new features are made available.

Remote Monitoring

Remote monitoring is achieved by simply installing a Pole Attached Concentrator (PAC) within 150ft of the LineTrackers. The PAC wirelessly links up with the LineTrackers to retrieve data and facilitates unsolicited and scheduled remote data transfer using Cellular, Satellite, TCP/IP or Radio communications. The sites can be queried by operators and the data can be integrated seamlessly to SCADA, Historians and other third party systems.

Viewing & Analysis

The intuitive LineView software is used to analyze LineTracker data files and provides graphical and table displays of event captures, waveforms and load profiles. Individual or multiple files can be viewed on the same graph and can be exported to Excel.



Technical Specifications

Line Voltage	*1 to 69kV Phase-to-Phase*
Frequency	*45-65Hz*
Circuits	*Overhead radial lines*
Conductor Range	*0.25" (6mm) to 1" (26mm) diameter*
Visual Indication	*High Intensity Red and Amber LEDs*
Fault Indication	*Red LED every 10 seconds*
Line Status	*Amber LED every 30 seconds*
Fault Indication Reset	*Time based and/or line restoration reset*
Communications	*Wireless Local and Remote options*
Local RF	*low powered, License free range 150ft (46m)*
Remote	*Cell (GSM/CDMA), TCP/IP, Landline, Satellite*
Systems Integration	*SCADA & Historian integration tools available*
Energy Storage	*1x2v 8Ah rechargeable sealed lead acid battery*
Power Source	*0.5W solar cell*
Operating Temperature	*-14F (-25C) to +120F (+65C)*
Survival Temperature	*-58F (-50C) to +185F (+85C)*
Housing Material	*UV Stabilized Polycarbonate and Aluminium Diecast*
Ingress Protection	*IP65 Weatherproof*
Dimensions	*14 H x 5 L x 5 W in. (35 H x 13 L x 13 L cm)*

Measured Parameters	*Current and Power (On/Off)*
Fault / Event Capture	*60 Sec RMS profile (I & E-Field)*
	Pre-event Line Loading
	Fault Current Magnitude up to 35kA
	Fault Current Waveform (12-cycles)
	E-Field Waveform % Change (12-cycles)
	Post-event Line Loading
Protection Operations	*Time to Trip*
	Number of Trips
	Inrush Current
Power Outage	*Time of Power-Off*
Power Restoration	*Time of Power-On and Outage Period*
Load Profiling	*User defined averaged profile (1-60 mins)*
Sample Rate	*Current 1200Hz, E-Field 600Hz*
Accuracy	*Current +1% of reading +2 A*
Memory Storage Capacity	*Rolling partitioned memory*
RMS Records (60sec)	*100+ events*
Fault Waveforms	*34*
Load Profiling	*Up to 85 days*
Weight	*4.4lbs (2kg)*

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Fax: +1 310 645-0923

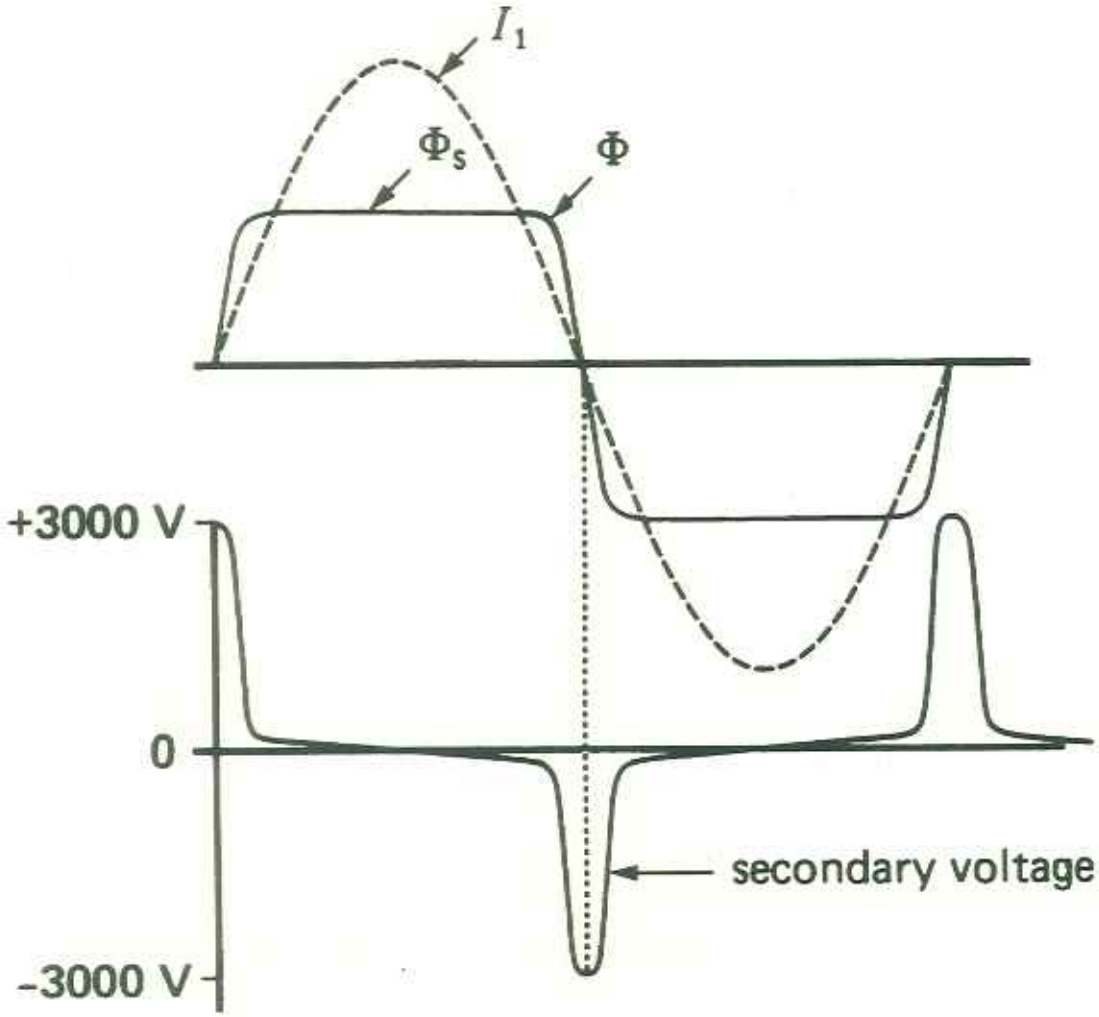
CHK GridSense Pty Ltd.
Unit 3 20-36 Nancarrow Av
Meadowbank, NSW 2114, Australia
Tel: +61 2 8878-7700
Fax: +61 2 8878-7788

GridSense
www.gridsense.net

Open Circuit CT

Figure 11-18 Primary current, flux, and secondary voltage when a CT is open-circuited.

Creates undesired saturation



Only $\frac{d\phi}{dt}$ creates V_{out}

Theodore Wildi
Electrical Machines, Drives, and Power Systems, 5e

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$S_{CT} = 100\,VA$ $\quad \frac{2000\,A}{5\,A}$

138 KV Standoff

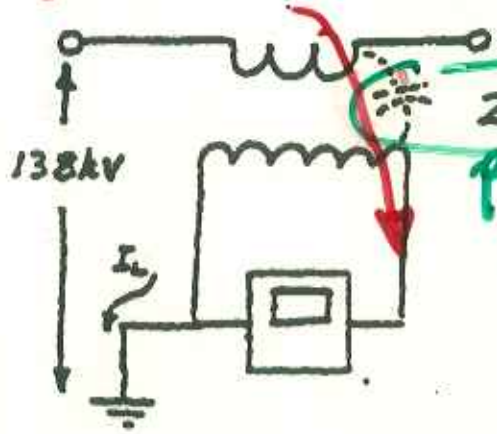
$i_d(C) = ?$

Given C Parasitic

wire / ins / wire

11-10

15



$$X_C = \frac{1}{2\pi f C} = \frac{1 \times 10^{12}}{2\pi \times 60 \times 250} = 10.6\ M\Omega$$

$$I_L = \frac{138\,000}{10.6 \times 10^6} \times 1000 = 13\,mA.$$

Note: a current of 13 mA is a strong current if it were to pass through a person's body.

i_R (through (insulation) R) $= 0$

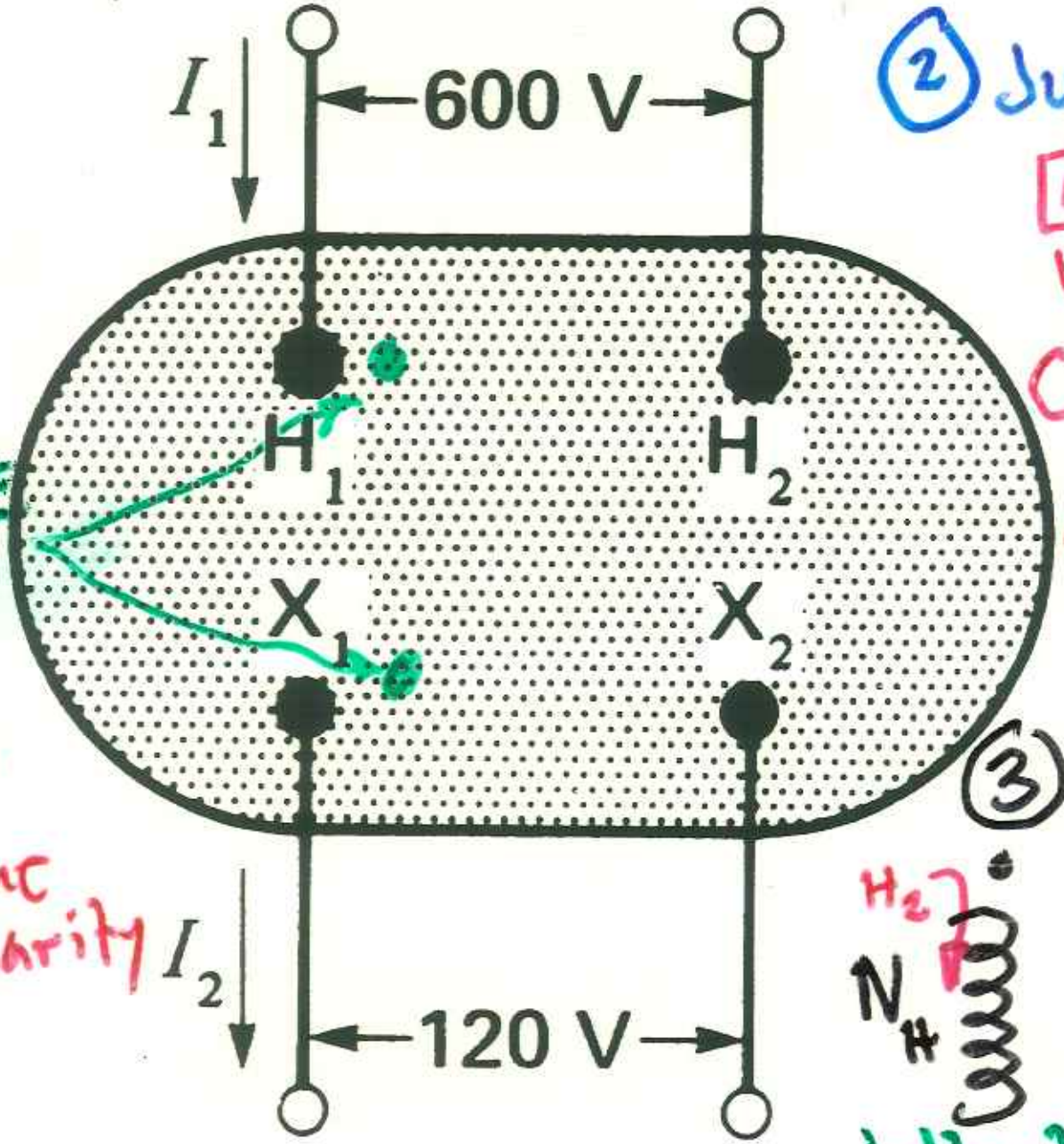
BUT

i_C (displacement current) is large!

Deadly!

Always ground CT!

Simple Transformer Review



(1) Dots
IEEE
Std
X_1 SAME
H JP
polarity

H_2 same
X_2 polarity

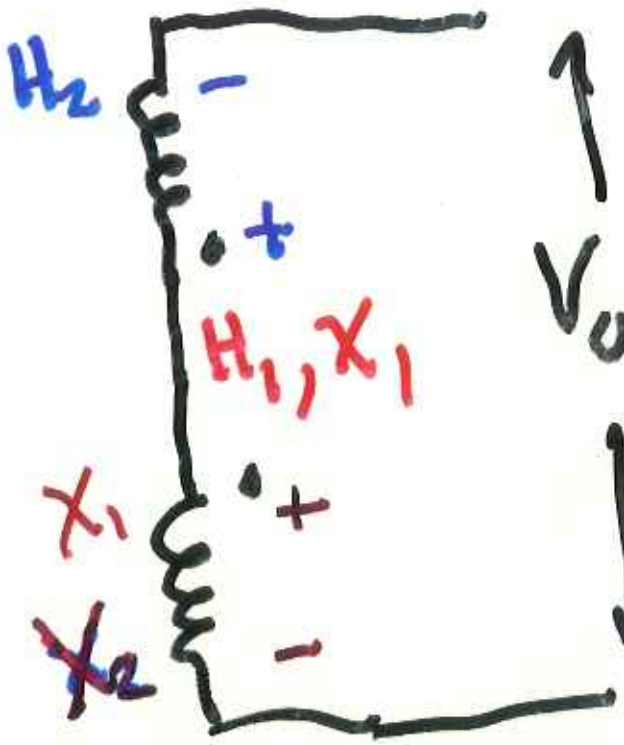
(2) Just 600 → 120
120 → 600
OR
Wiring
Other clever
Possibilities
?

(3) i flow vs Dots

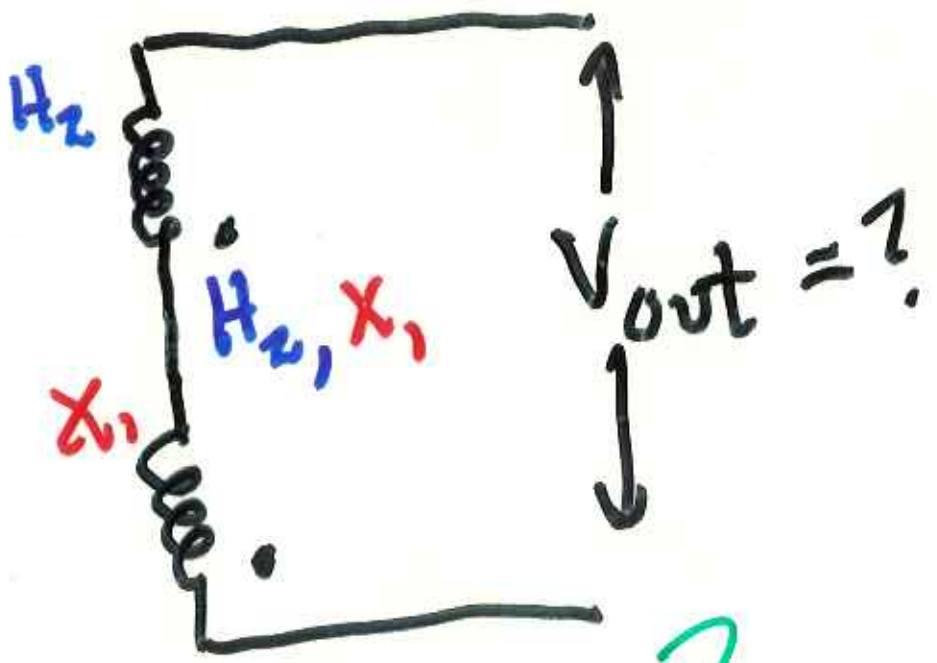
What about
i flows in Coils?

(4) $V_{H1} - V_{X2} = ?$

Other Wirings

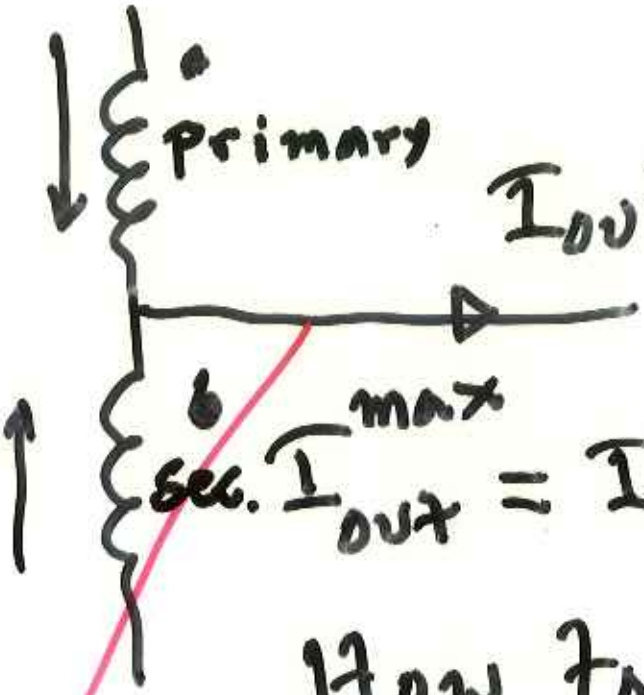


V(H1 − X2) = ?



Input choices ?

V_{in}	V_{out}
120	720 or 480
600	720 or 480



$I_{out} = ?$

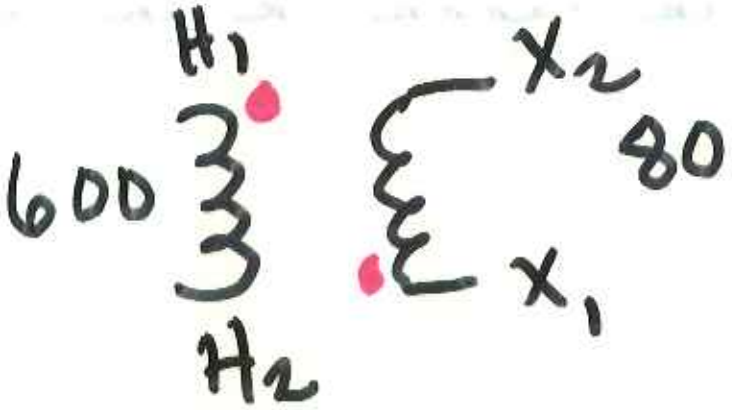
$I_{out}^{max} = I_{p}^{max} + I_{sec}^{max}$

How to exploit?

Autotransformer

Coming attraction

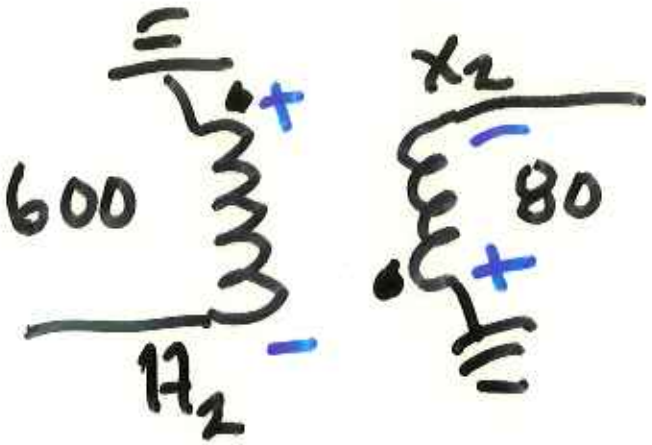
Wire rating?



Both sides are isolated

$V_{H1} - V_{X2} = ?$ ⇒ 0 Why?

Short H_1 to X_1 and ground!

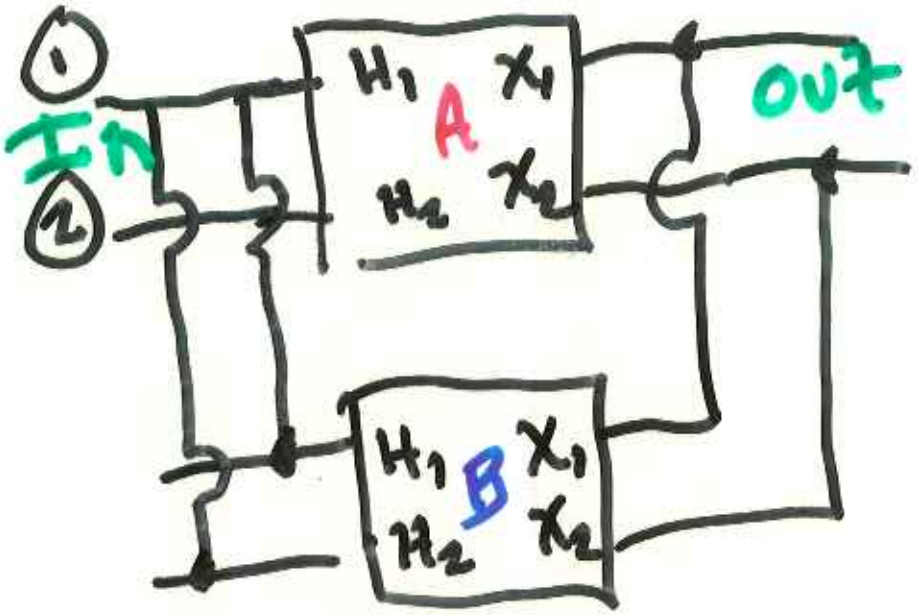


$V_{H2} - V_{X2} = ?$

−520 Why

Two Parallel Transformers

Fig 10.34 pg 219



Great get greater I_{out} @ V_{out}

What if electrician miswires $H_1^A \rightarrow H_2^B$

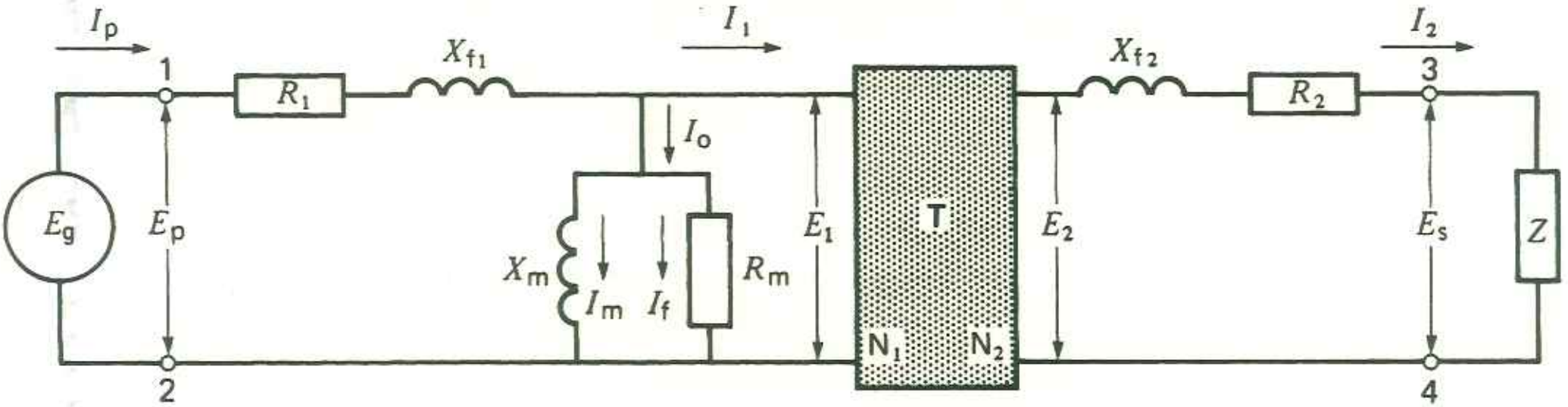
$H_2^A \rightarrow H_1^B$

eg reversed the terminals ?

Short circuit

Less Power TO THE *People*

How to determine / measure transformer these parameters?



23 a

X_m R_m — Short Circuit Test?

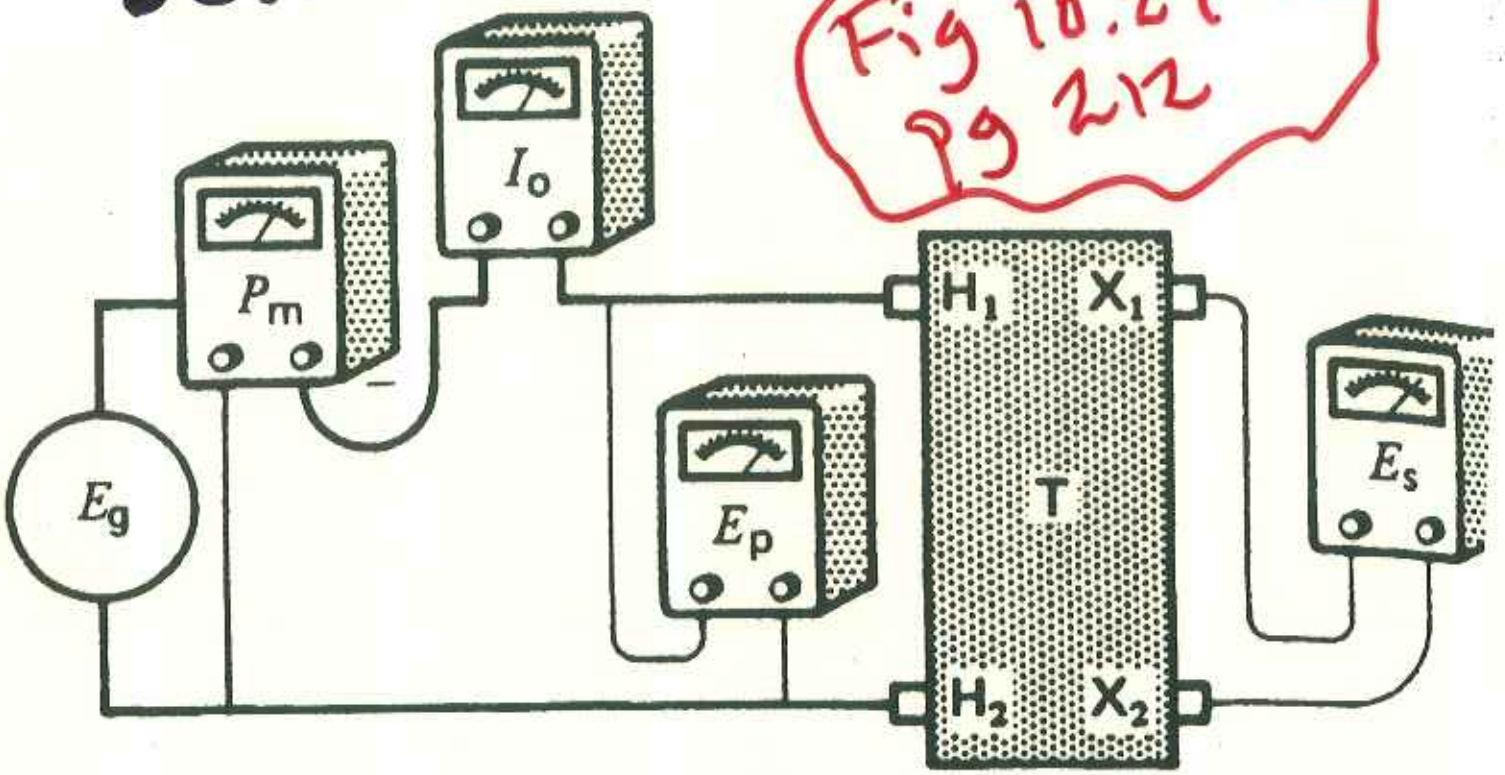
Open Ckt Test?

$\begin{pmatrix} X_\ell \\ X_f \end{pmatrix}$ R_{wire} measured by?

set

Below is which test?

Fig 10.27 pg 212



Open Ckt Test

$P = \frac{V^2}{R_m}$

$$\frac{E_p}{I} = ?$$

Role of power motor

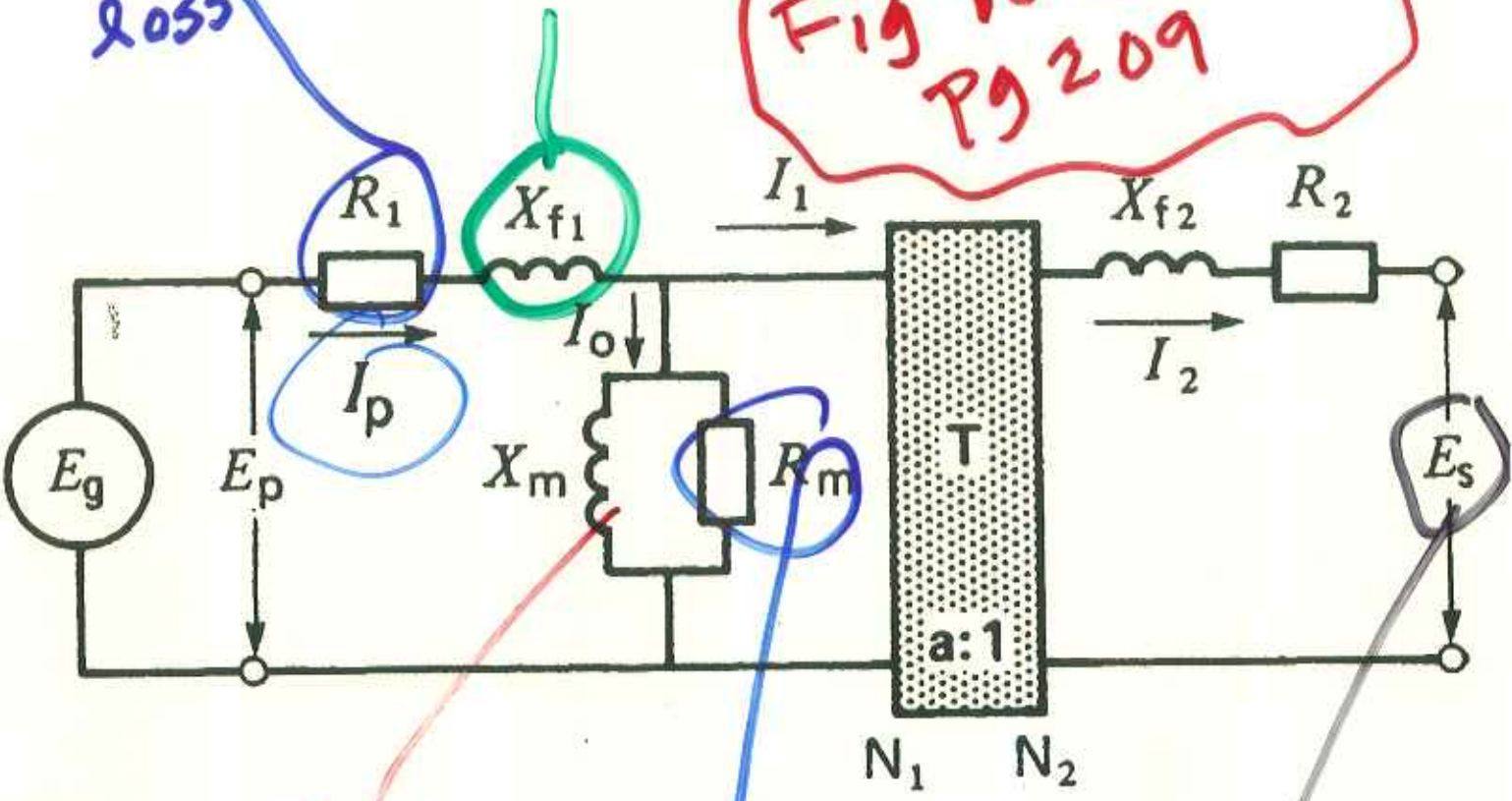
Simple Eq Circuit

10
22

leakage
flux
leakage L

Wire
R
loss

Fig 10.20
Pg 209



Mag
i
drawn
from Eg
at 90°

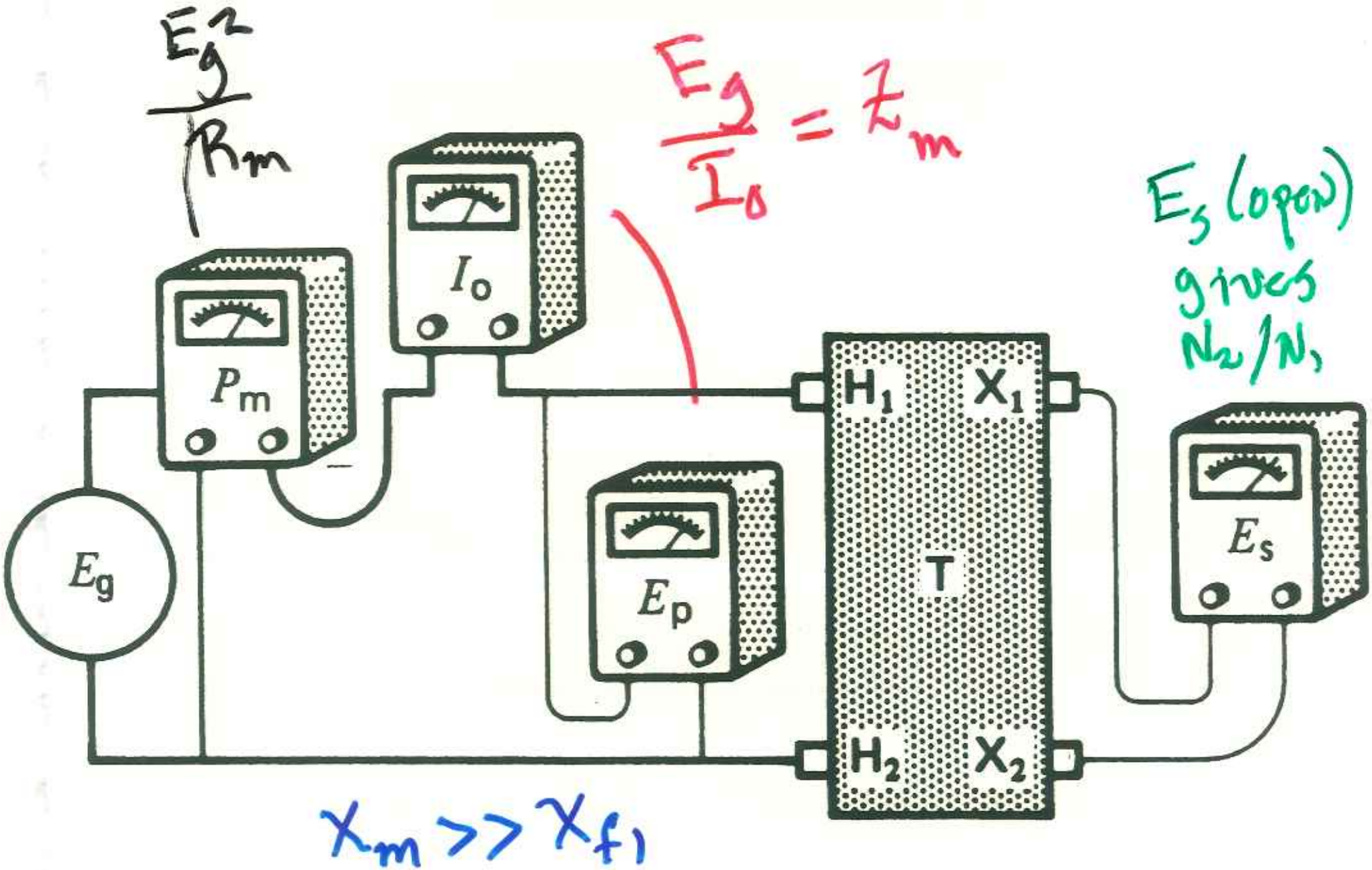
Hysteresis and
Eddy i
Losses

Open
$I_1 = ?$

0

$I_p = 0$ for open load?

For good power trf $|X_m| \uparrow R_m \uparrow$

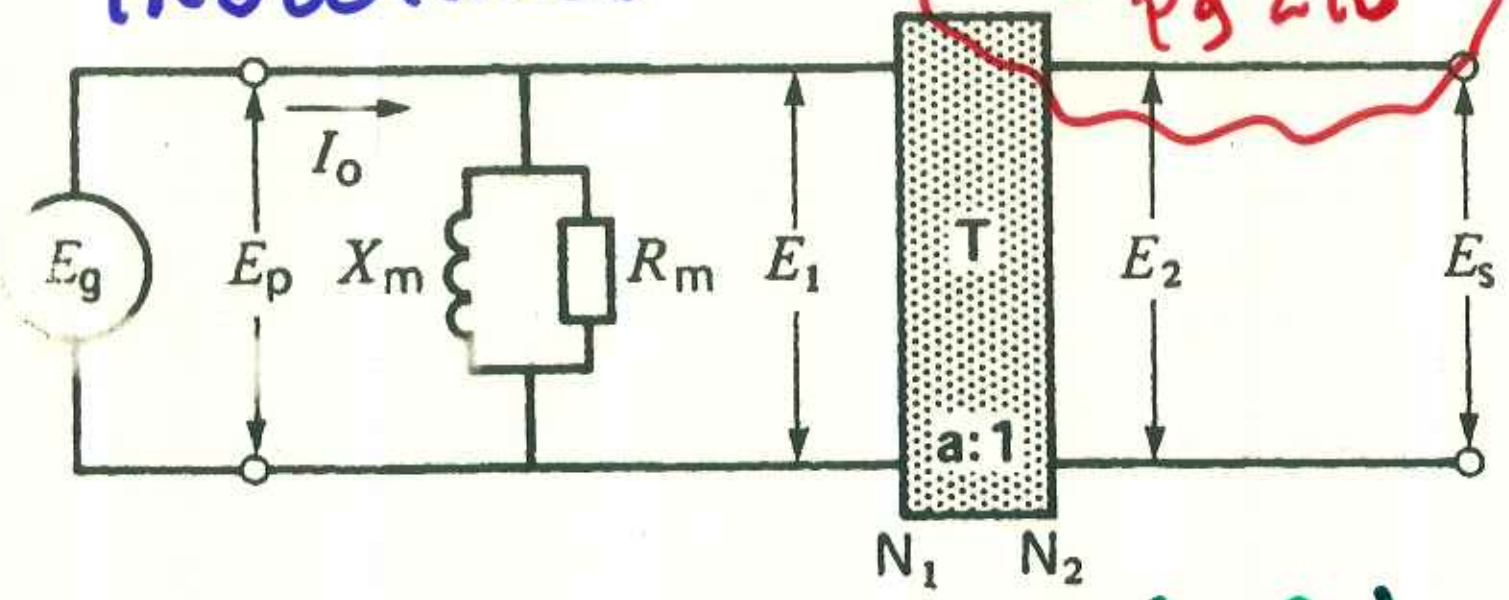

E_g^2
R_m
$\frac{E_g}{I_0} = Z_m$
E_s (open)
gives
N_2/N_1
P_m
I_o
E_g
E_p
H_1
X_1
T
H_2
X_2
E_s
$X_m >> X_{f1}$

24 Open Circuit Trf. Test

$$\frac{E_g}{I_0} = Z_{in} \approx R_m + X_m$$

We can measure L_m the transformer magnetizing inductance

Fig 10.2 HC
Pg 210



We measure R (core loss)

24
a

set Which test below?

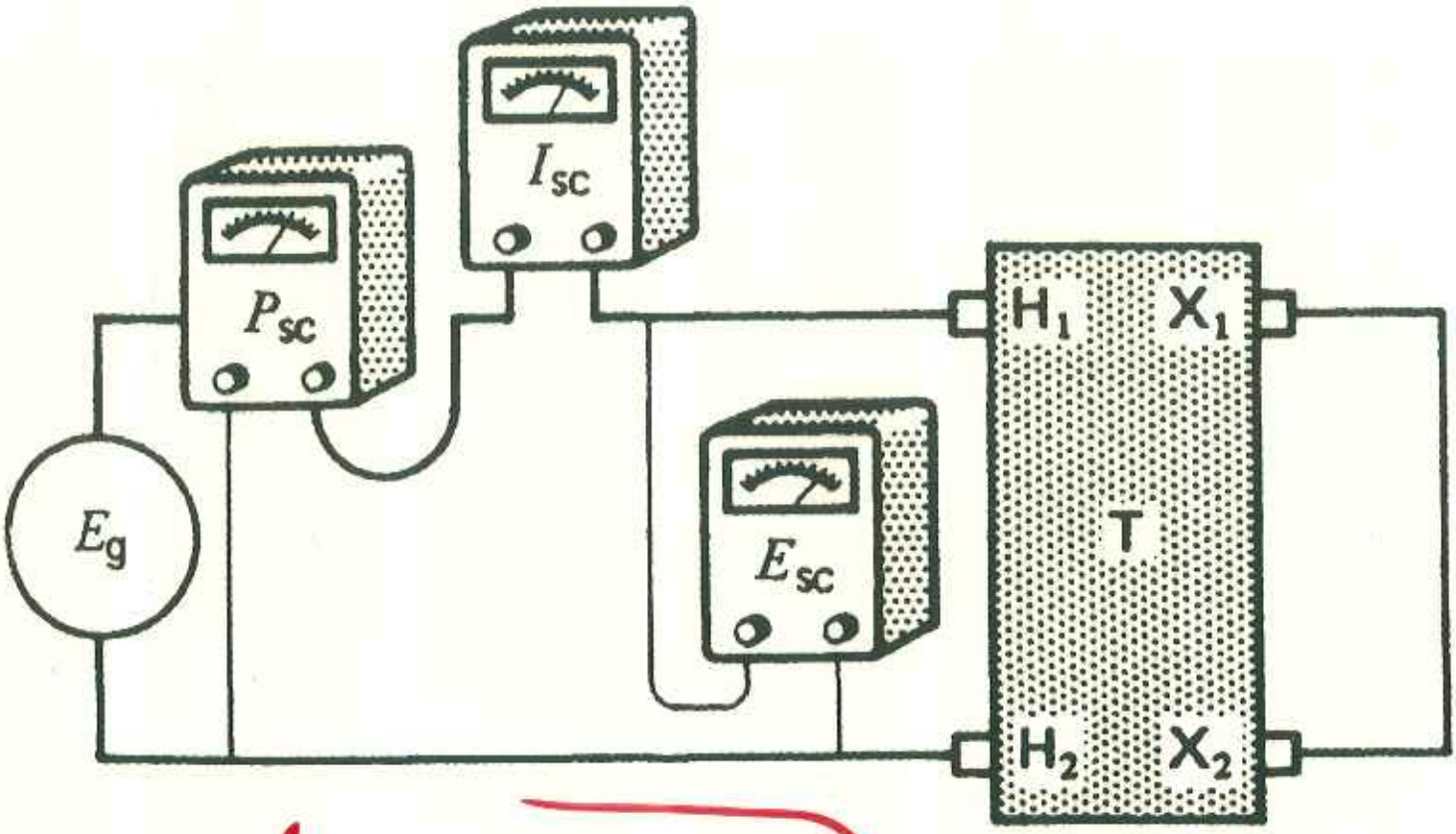


Fig 10.28
Pg 213

$X_\ell = ?$

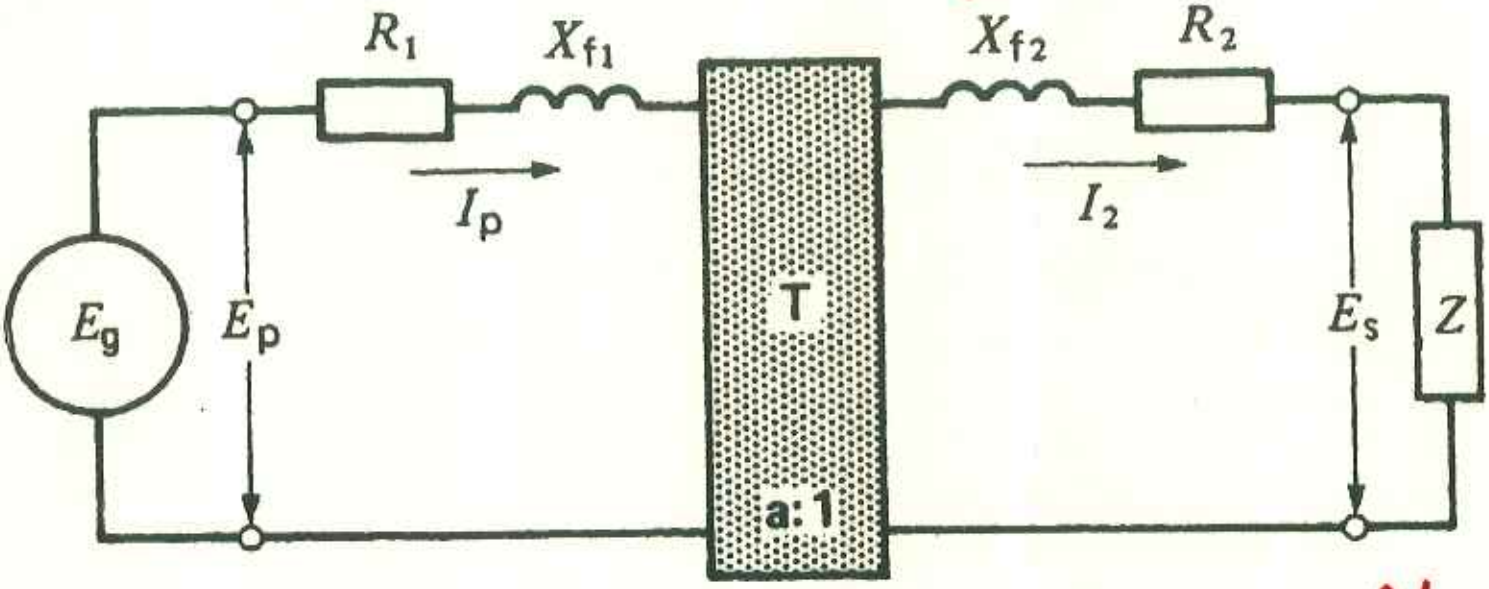
$R_{wire} = ?$

25 Short Circuit (Full load) Transformer Measurement

We measure: $I_p >> I_{lm}$

(1) Wire Resistances

Fig 10.22 pg 210



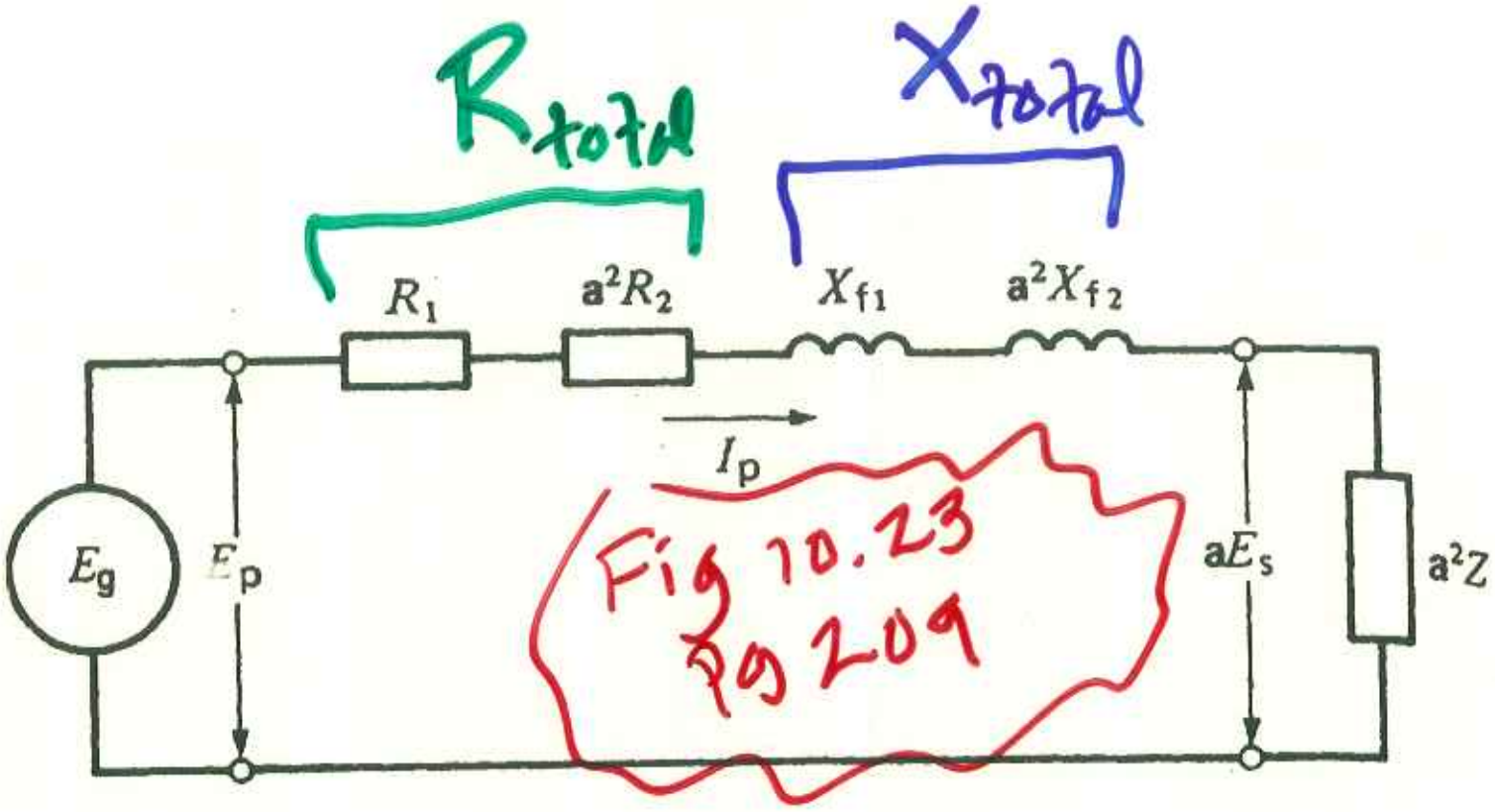
2. Leakage Inductance: X_{fx}

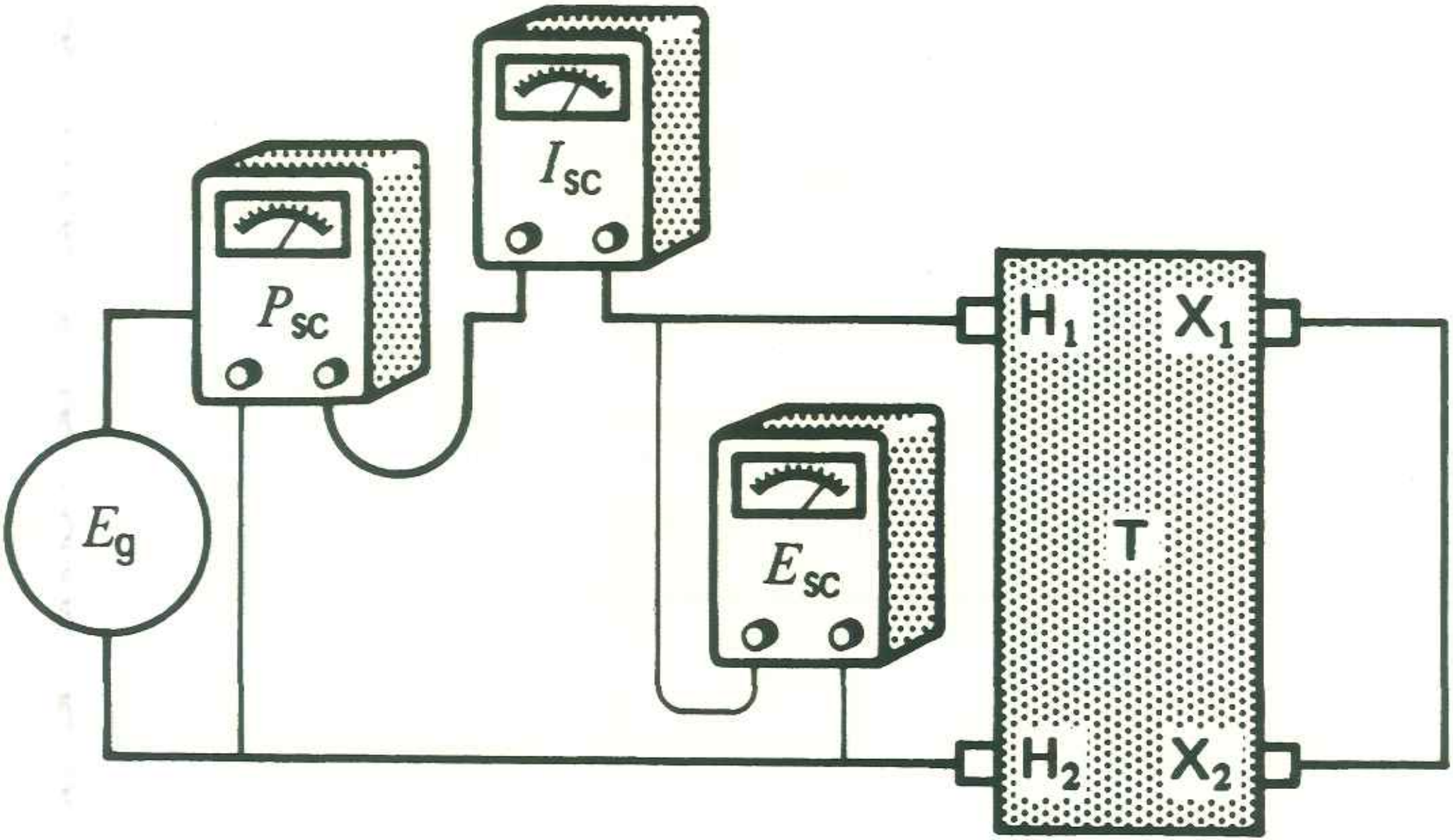
$Z_{load} \rightarrow 0$ I_{sc} is I_{max} (rated)

$$\frac{E_g}{I_p} = Z_p = R_p + jX_p$$

$R_p = R_1 + a^2 R_2$

$X_p = X_{f1} + a^2 X_{f2}$


R_{total}
X_{total}
R_1
a^2R_2
X_{f1}
a^2X_{f2}
I_p
E_g
E_p
aE_s
a^2Z
Fig 10.23
pg 209


I_{SC}
P_{SC}
E_{SC}
E_g
H_1
X_1
T
H_2
X_2

In power transformers

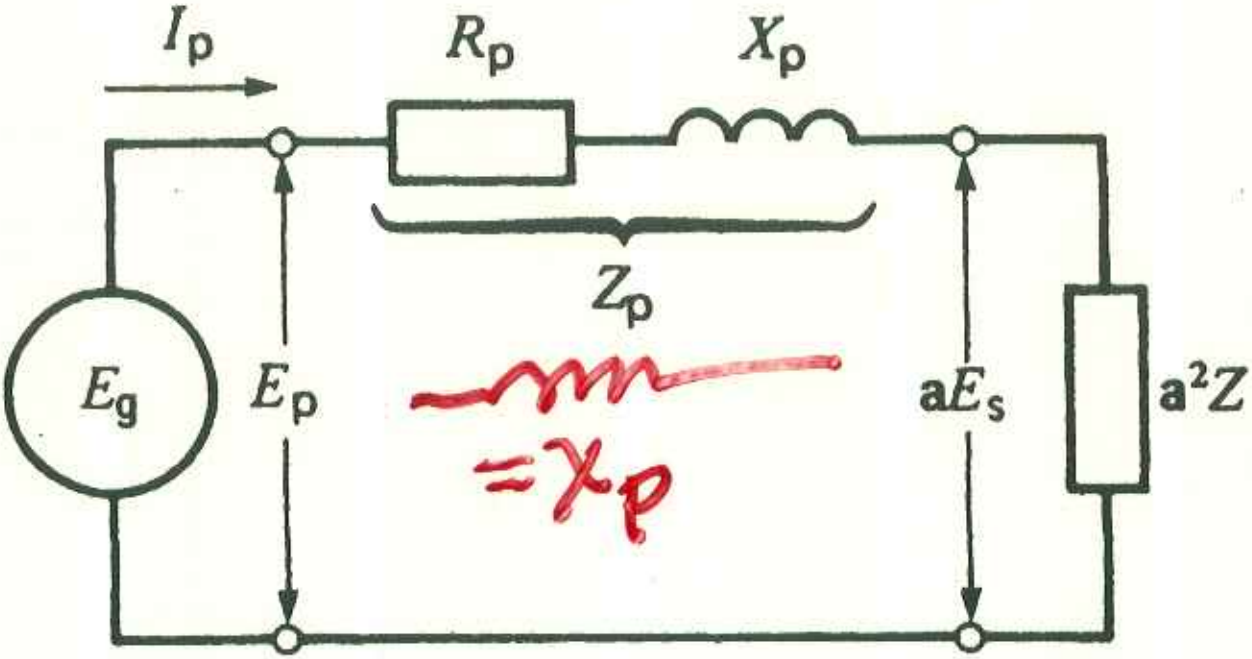
$X_p >> R$ (low P loss)

We design for P this case

$S > 500\,kVA$ Trf

even

$S > 300\,kVA$

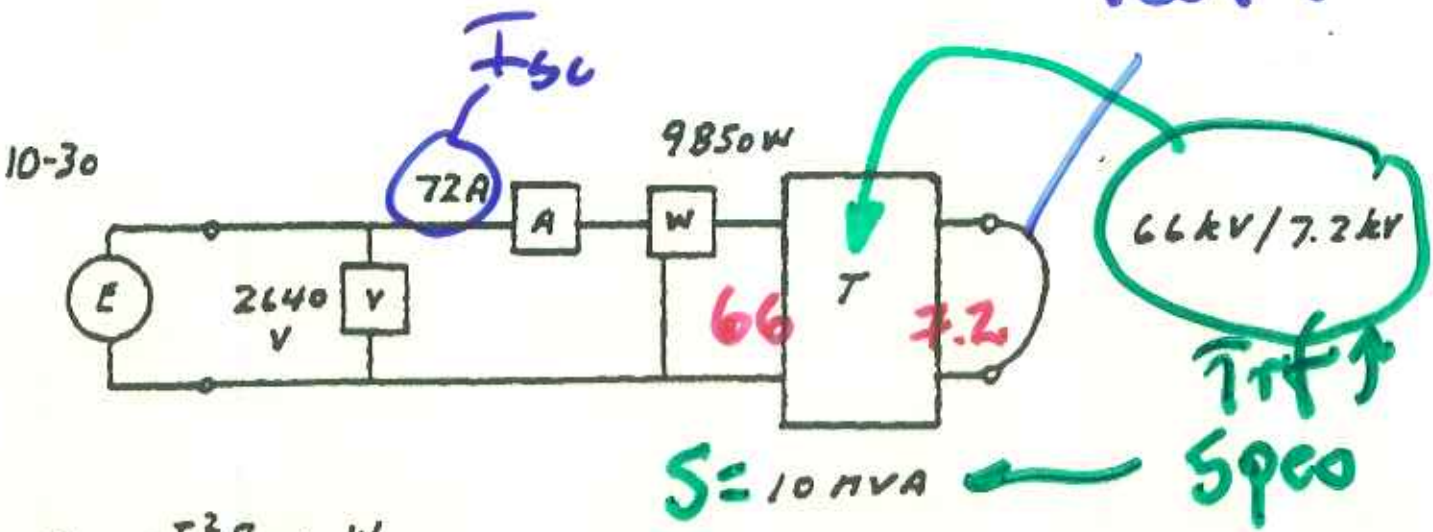


Often at full load only

X_p represents the entire transformer

sct

Test?



28

a. $I^2 R_p = W$

$72^2 \times R_p = 9850 \quad \therefore R_p = 1.9\ \Omega$

$Z_p = E/I = 2640/72 = 36.67\ \Omega$

$\therefore X_p = \sqrt{Z_p^2 - R_p^2} = \sqrt{36.67^2 - 1.9^2} = 36.6\ \Omega$

b. $Z_{np} = \frac{66000^2}{10 \times 10^6} = 435.6\ \Omega$ Base Z_p in primary

c. percent impedance $= \frac{36.27}{435.6} \times 100 = 8.4\ \%$.

$$\text{Rated } I_p = \frac{S}{V_p} = ?$$

$$R_p = R_{w1} + n^2 R_{w2}$$

$$X_p = X_{p1} + n^2 X_{s2}$$

Why trf in ||?

Need I_{max} for load but NO trf

- Need more I for load
  using existing transformers
- S (one trf) limited
  but two $S_T = S_1 + S_2$

S_A

How to wire?

Which is HV? LV?

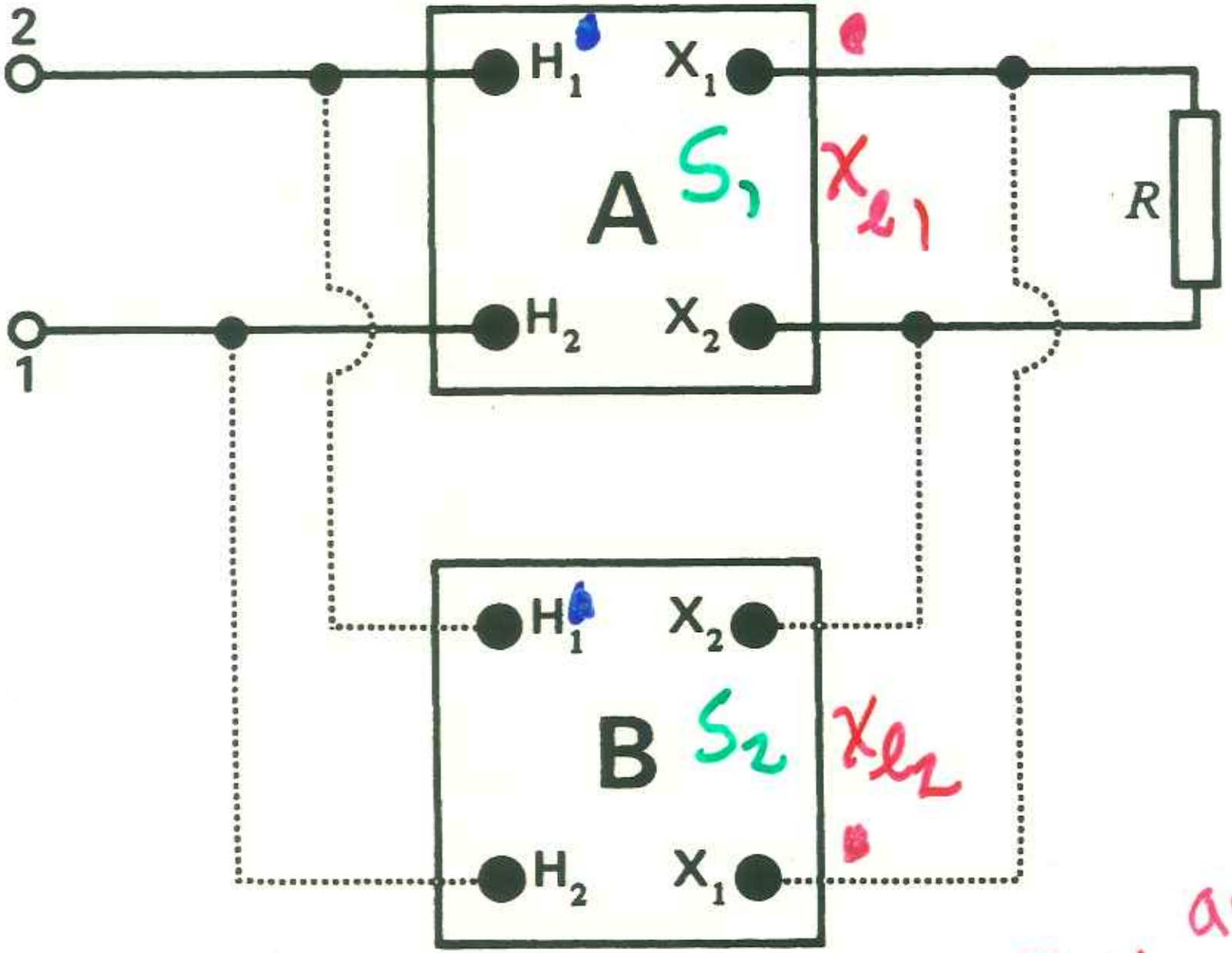
S_B

Issues for "i sharing"?

How to get I_{max} from S_{rating}

$$S_A \neq S_B$$

Note Phasing is key

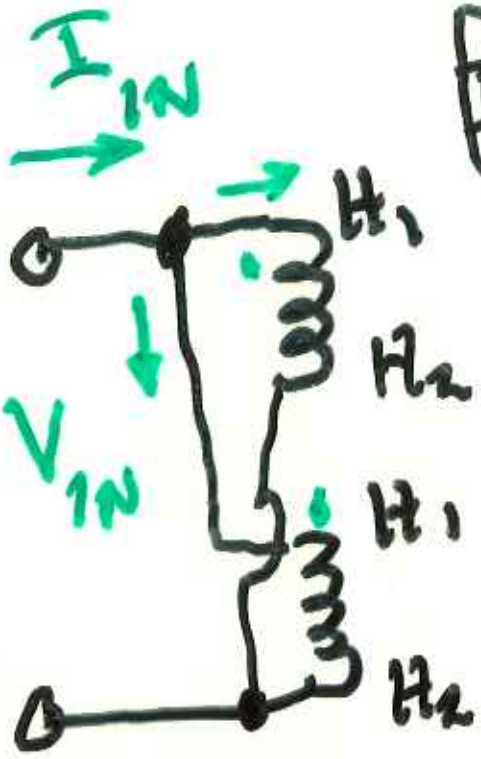


Why Best if $S_1 = S_2$? $X_{l_1} = X_{l_2}$ and

Wire Trf in Parallel

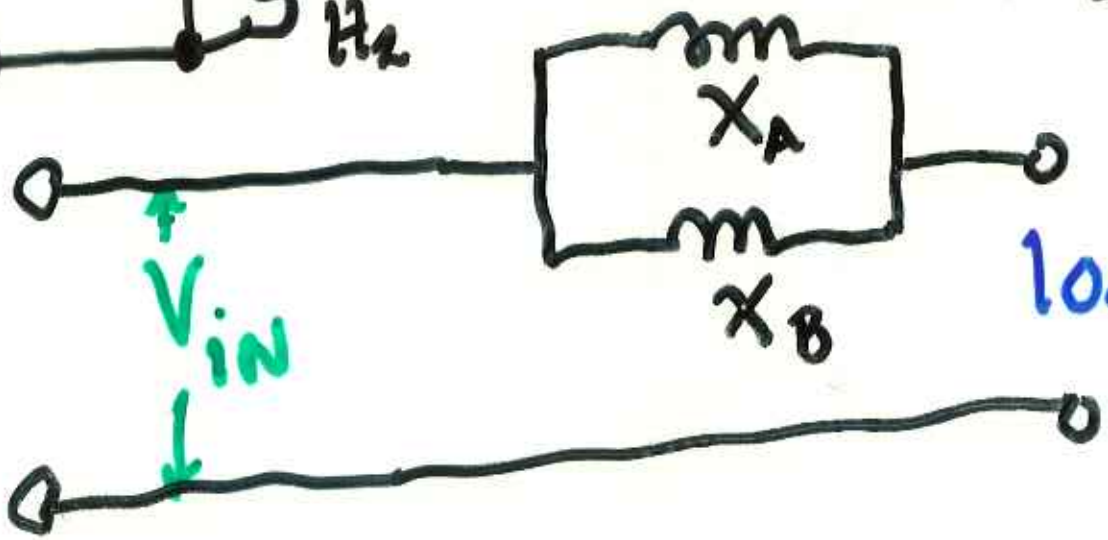
Why? Same S ? Different S?

Identical Trf

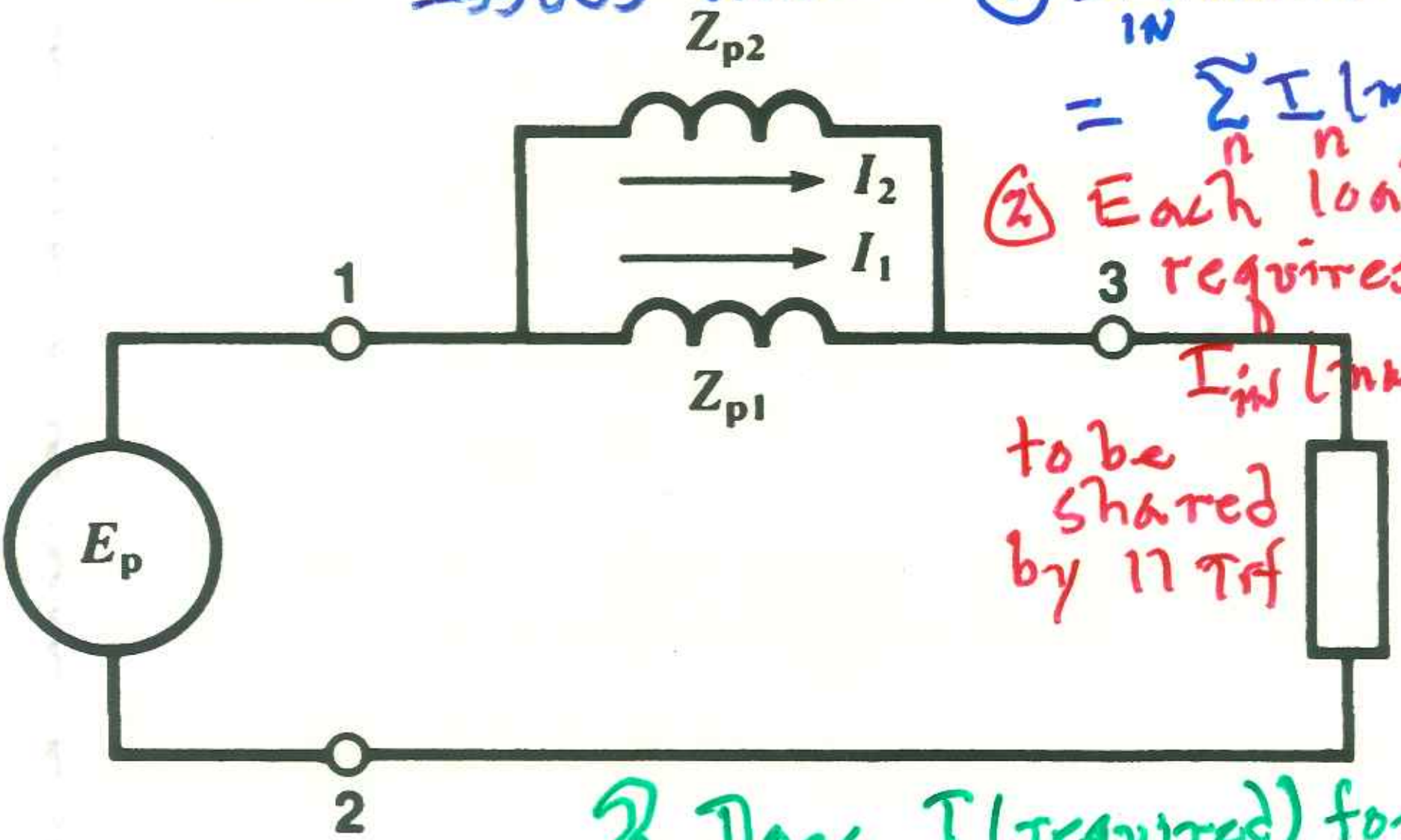


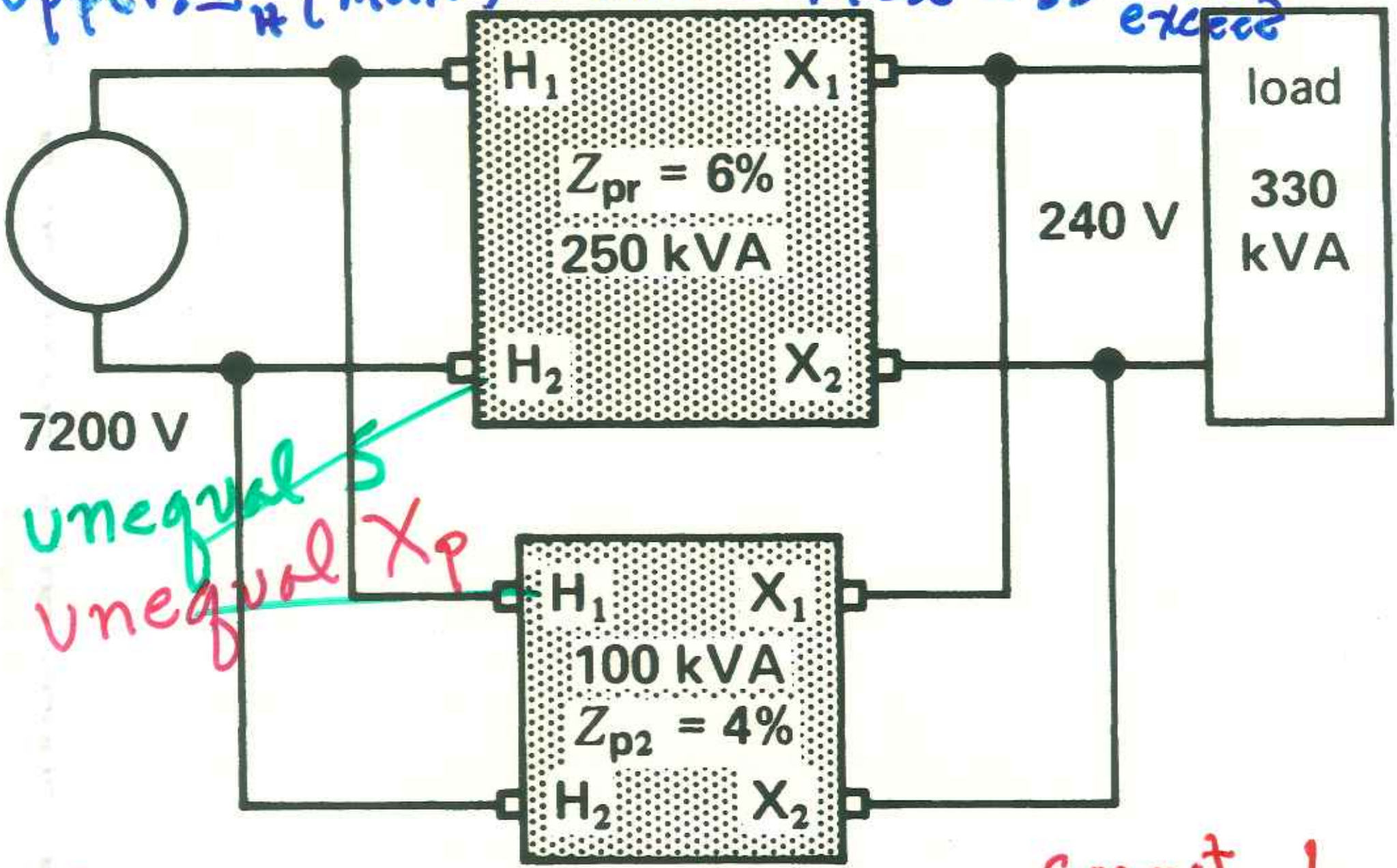
$I_{IN}^{max} = ?$ $S^{max} = ?$

Each trf can handle $S_{max} = I_{max} V_{IN}$



What if trf are Not identical $X_A \neq X_B$


Issues are?
(1) I_{IN} (max)
$= \sum_n I_n$ (max)
Z_{p2}
I_2
I_1
1
3
Z_{p1}
(2) Each load requires I_{in} (max) to be shared by n Trf
E_p
$a^2 Z_L$
2
(3) Does I (required) for each Trf ever exceed I (rating) ?


Upper: $I_H(max) = 250kVA/7200 = 35$ Cannot exceed
H_1
X_1
$Z_{pr} = 6\%$
250 kVA
H_2
X_2
load
330 kVA
240 V
7200 V
unequal S
unequal X_p
H_1
X_1
100 kVA
$Z_{p2} = 4\%$
H_2
X_2
Lower: $I_H(max) = \frac{100kVA}{7200} \simeq 14$
Cannot exceed!

41

$I_{primary}^{mxf} = \frac{330\,kVA}{7200} = 46\,A$

$I_p >$ Nominal of either trf

Fortunately Σ rated currents exceeds

$\Sigma I_n = 35 + 14 = 49\,A$

BUT

$I_{n1} = 34.7\,A$

$I_1 = 28.8\,A$

$I_{n2} = 13.9\,A$

$I_2 = 17.2\,A$

$I_L = 46\,A$

$Z_{p1} = 12.4\,\Omega$

$Z_{p2} = 20.7\,\Omega$

Z 157 Ω

$Z_{B1} * PU$ .06 $\frac{(7200)^2}{250}$ 207

$Z_{B2} * PU$ .05 $\frac{(7200)^2}{100}$ 518

MAX

Fig 10.34b pg 221

$\frac{1}{(7200)^2}$ 330kVA

$I_p = 46\,A$ divides as

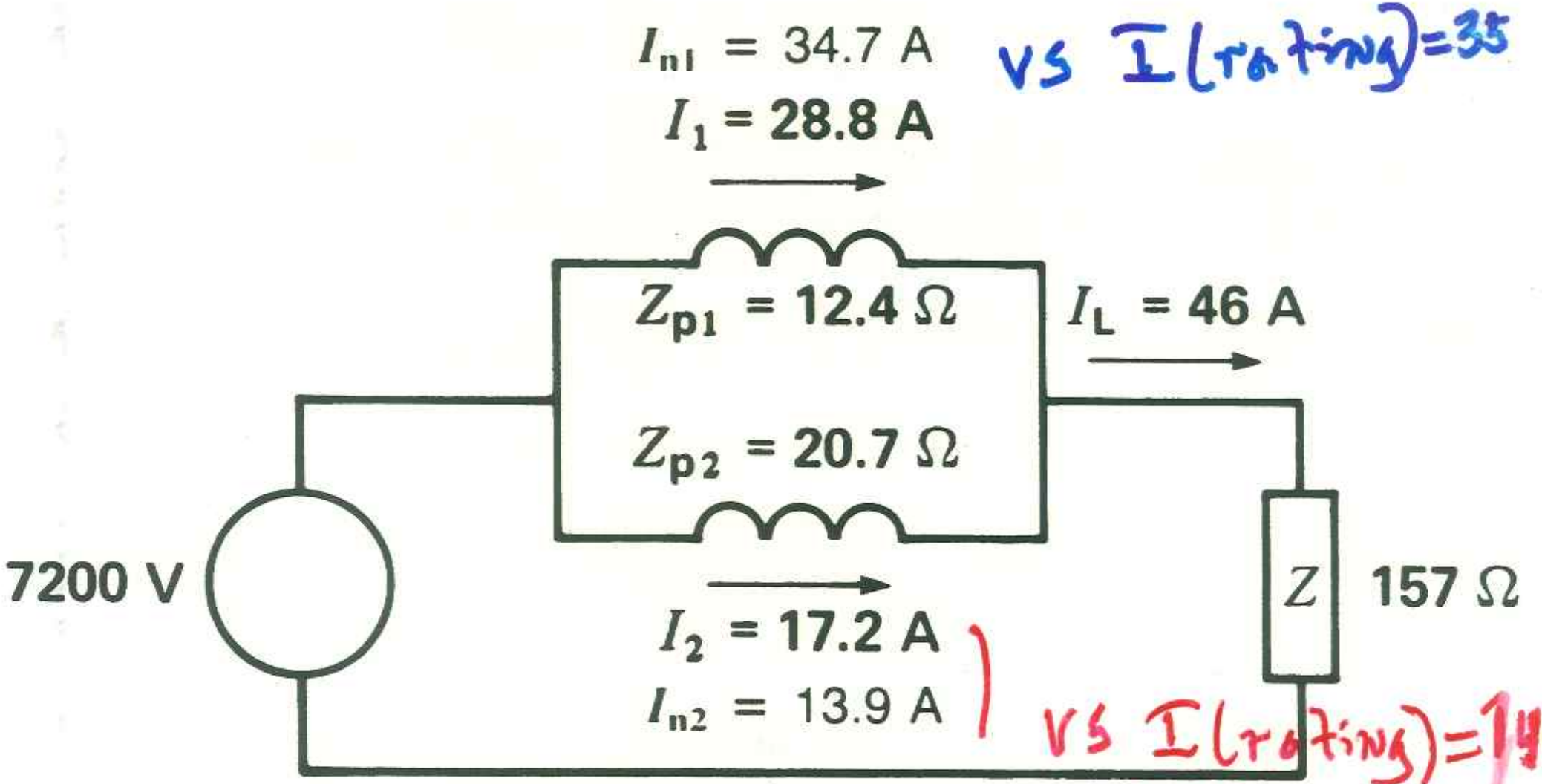
$I_1 = \left\{\frac{20.7}{12.4+20.7}\right\} 46 = 28.8$ OK $< I_{n1} = 35$

$I_2 = \left\{\frac{12.4}{12.4+20.7}\right\} 46 = 17\,A$? OK

NG $> I_{n2} = 14$

compared to rated current?

I_R = 14 Ouch



vs I(rating)=35

vs I(rating)=14

Whoa! over limit ☹

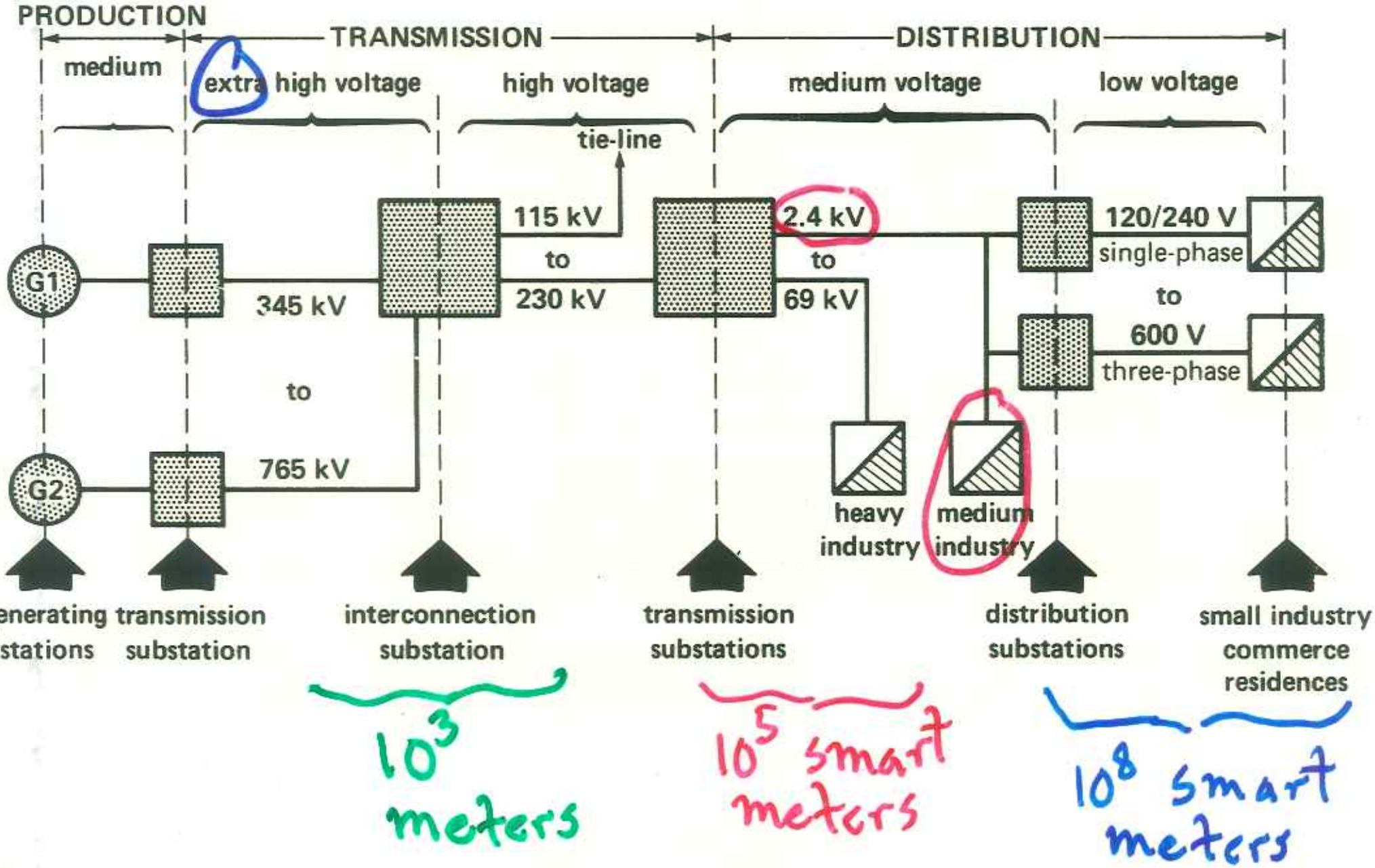
Electric Utility Companies

- Public Power (municipals, PP districts, etc)
- Cooperatives
- Investor Owned
- Private

Bulk Transmission System

Facility Site Selection: Physical Criteria

- **close to existing transmission lines**
- **accessibility to existing ROW**
- **close to load**
- **cost of land**


PRODUCTION
TRANSMISSION
DISTRIBUTION
medium
extra high voltage
high voltage
medium voltage
low voltage
tie-line
G1
G2
345 kV
to
765 kV
115 kV
to
230 kV
2.4 kV
to
69 kV
120/240 V
single-phase
to
600 V
three-phase
heavy industry
medium industry
generating stations
transmission substation
interconnection substation
transmission substations
distribution substations
small industry commerce residences
10^3 meters
10^5 smart meters
10^8 smart meters

Why use DC?
When employ DC?

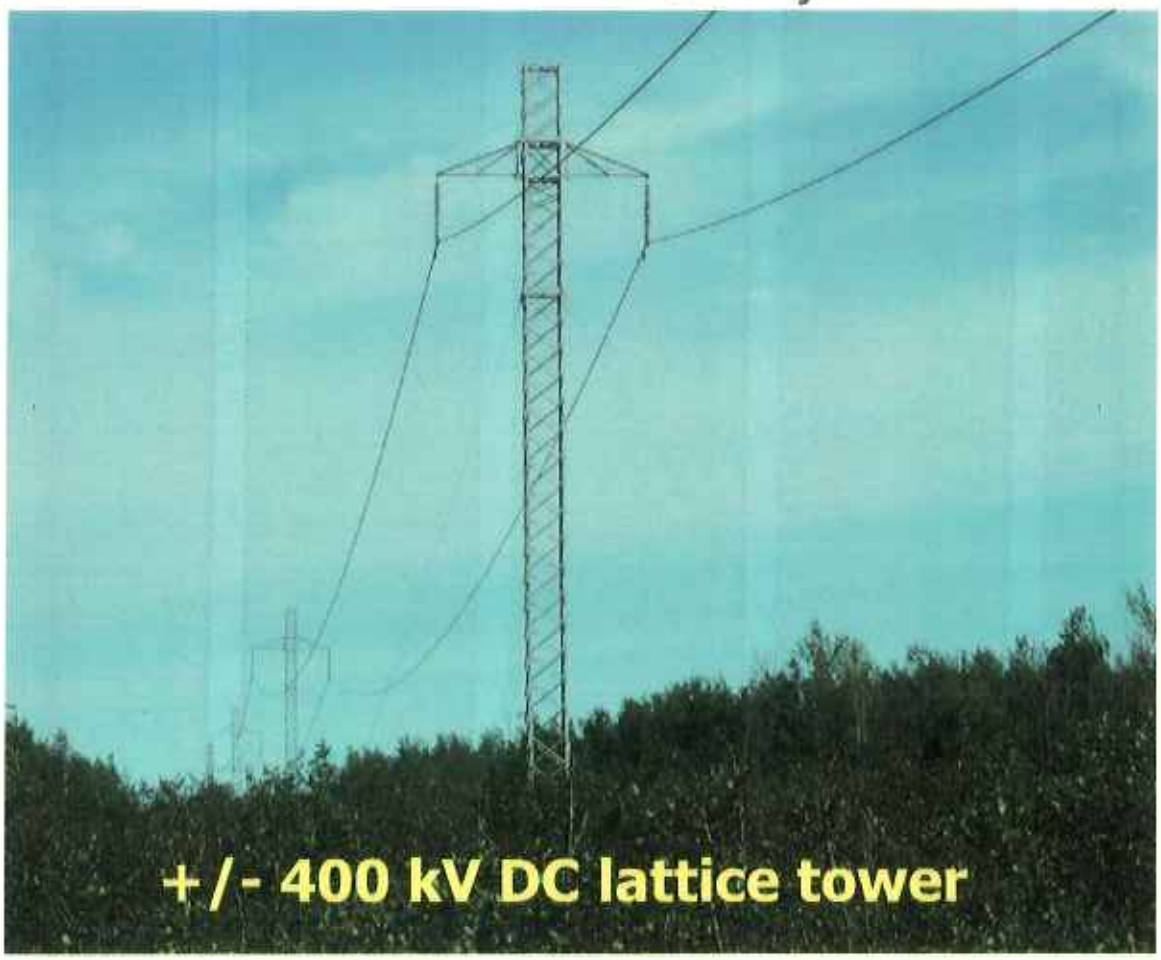
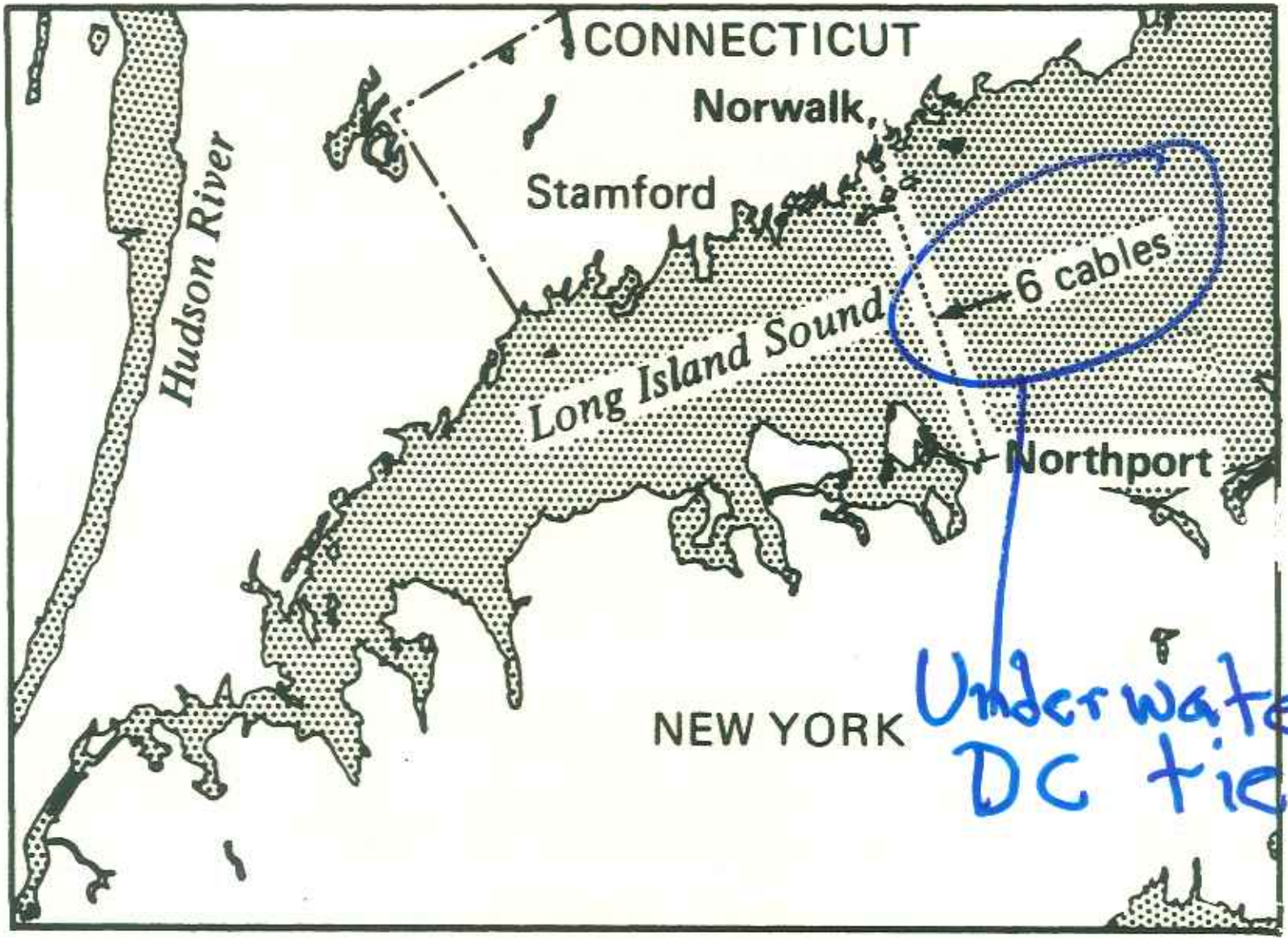


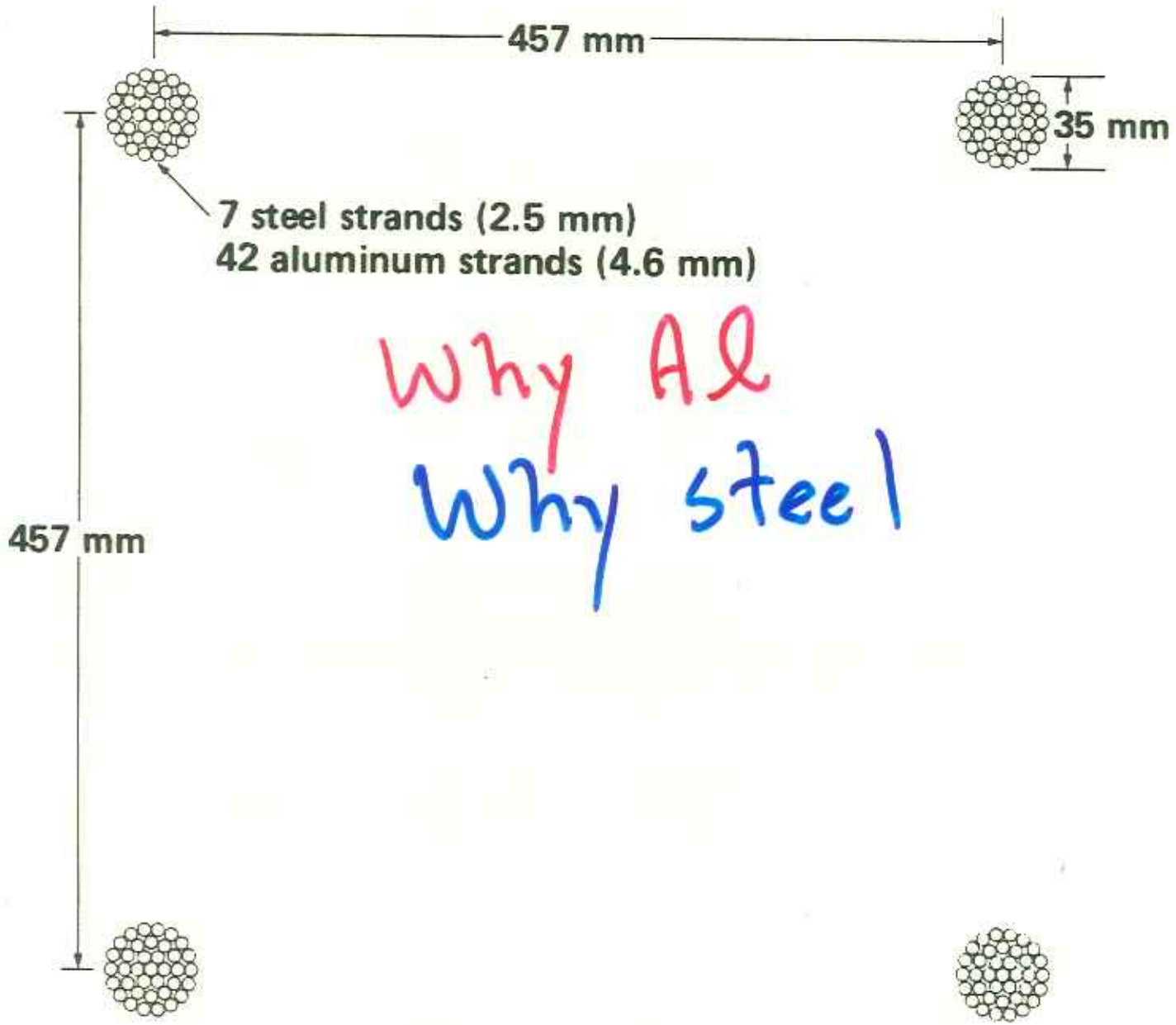
Fig 25.42 pg 735



Bulk Transmission System

Hardware: Transmission Lines

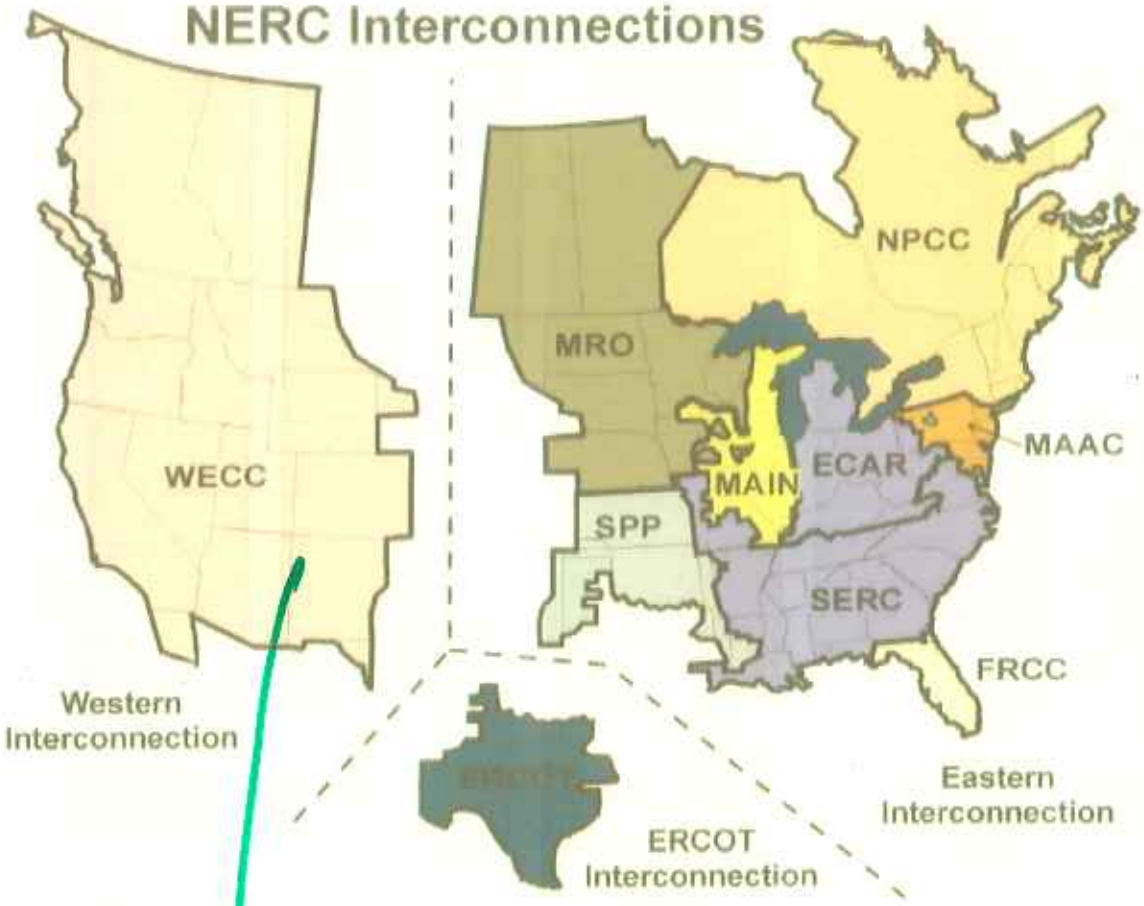
- **overhead conductors**
  - **aluminum conductor steel reinforced (ACSR)**
  - **all aluminum (AA)**
  - **copper**
  - **high strength steel (HSS) – static wire**
  - **fiber optic core**



Why Al

Why steel

Three Regions Each at unique f



WAMPA site visit

Bulk Transmission System

Laws of Physics

- **electricity follows its own path**
  - **can not be legislated**
  - **does not honor control area boundaries**
  - **does not honor international borders**

Electric Utility Industry Organization

- Federal Energy Regulatory Commission (FERC)
- Public Utility Commissions (PUC)
- North American Electric Reliability Council (NERC)

Electric Utility Industry Organization

Public Utility Commissions (PUC)

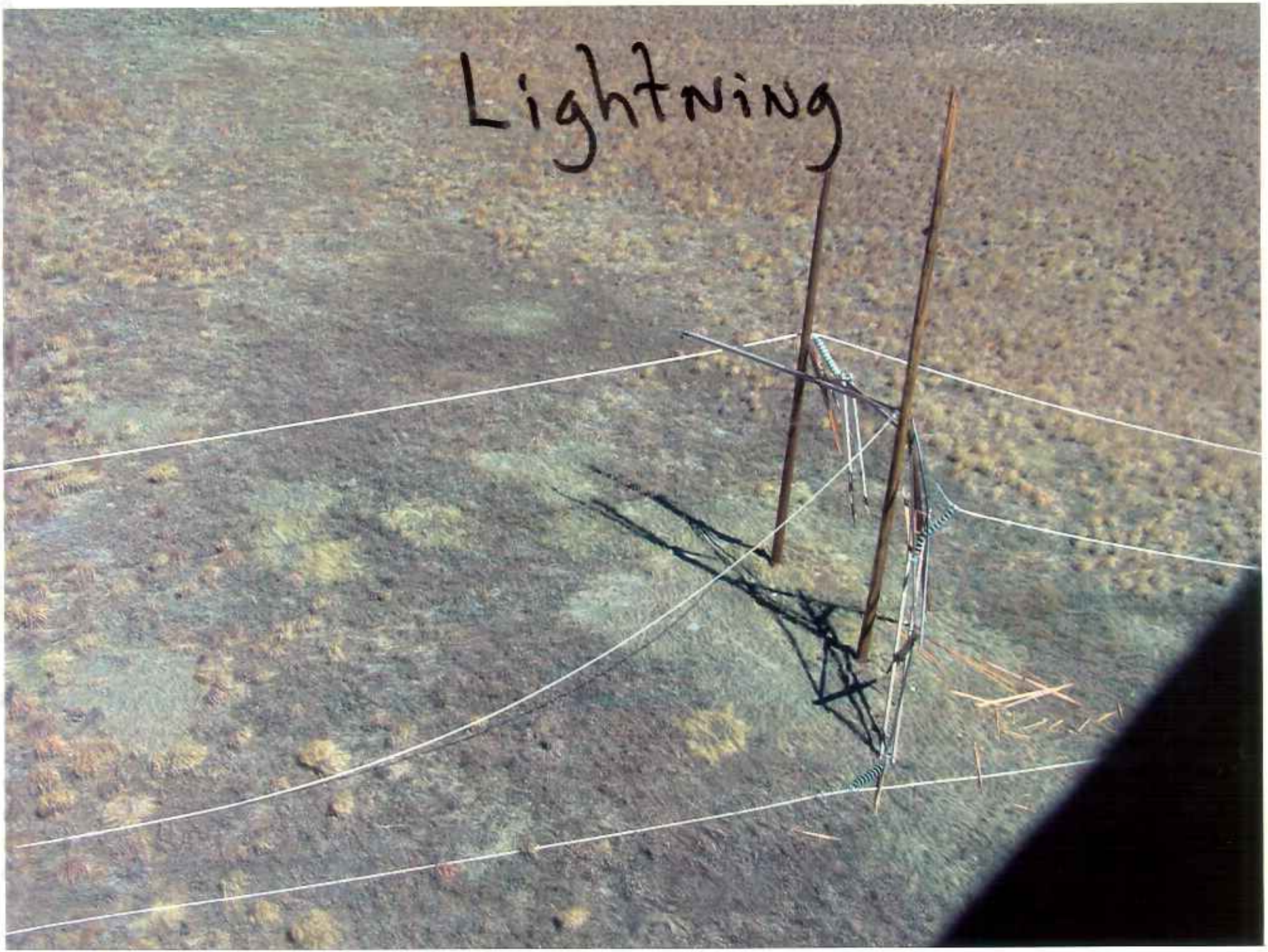
- State Agencies
- Jurisdiction over retail sales
  - public power and cooperatives exempt
  - regulate distribution system use
  - approve retail rates
  - establish retail programs (conservation, new tech, etc)

Safety is a critical design criteria!

How will it be operated?

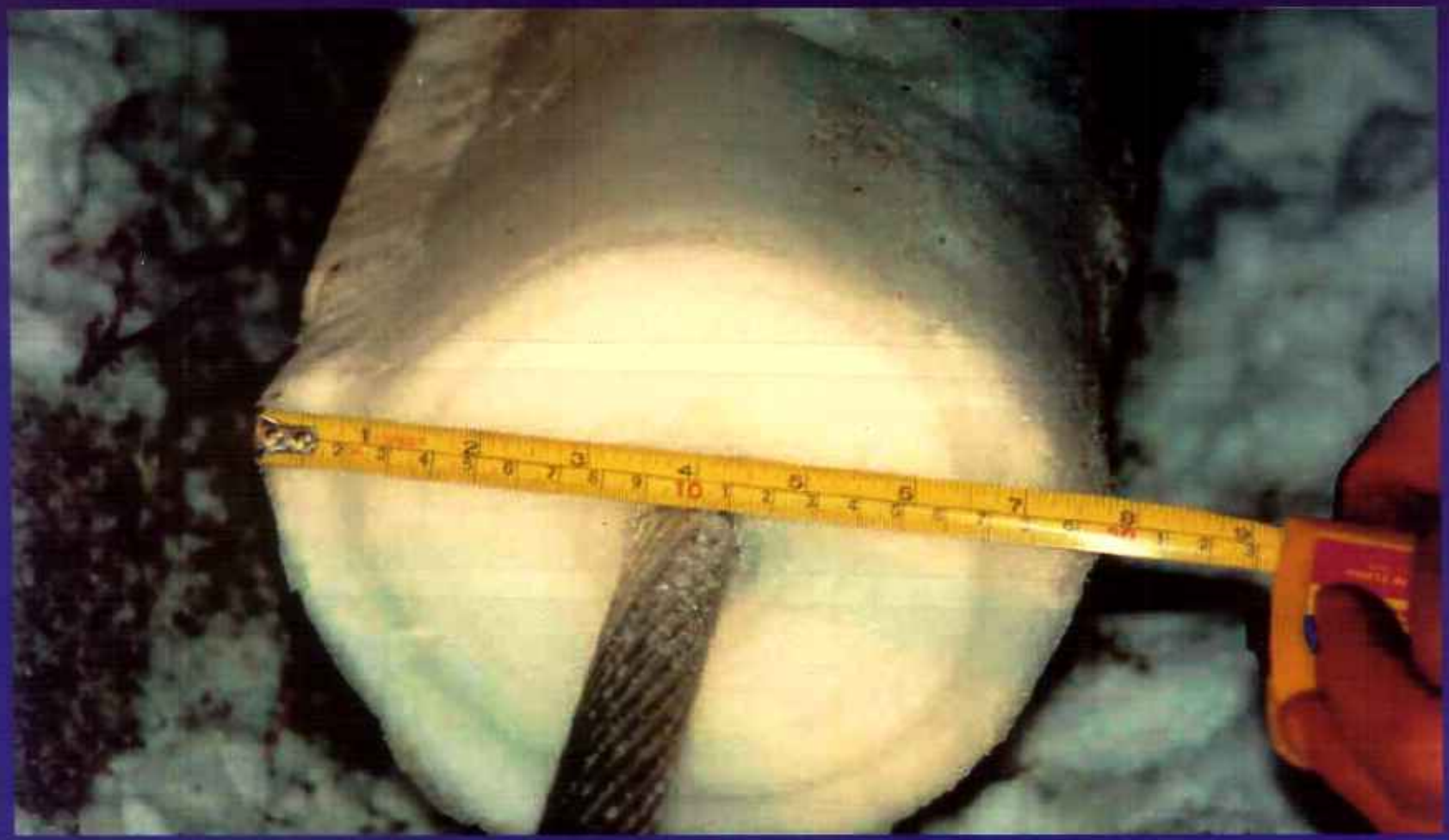
How will it be maintained?

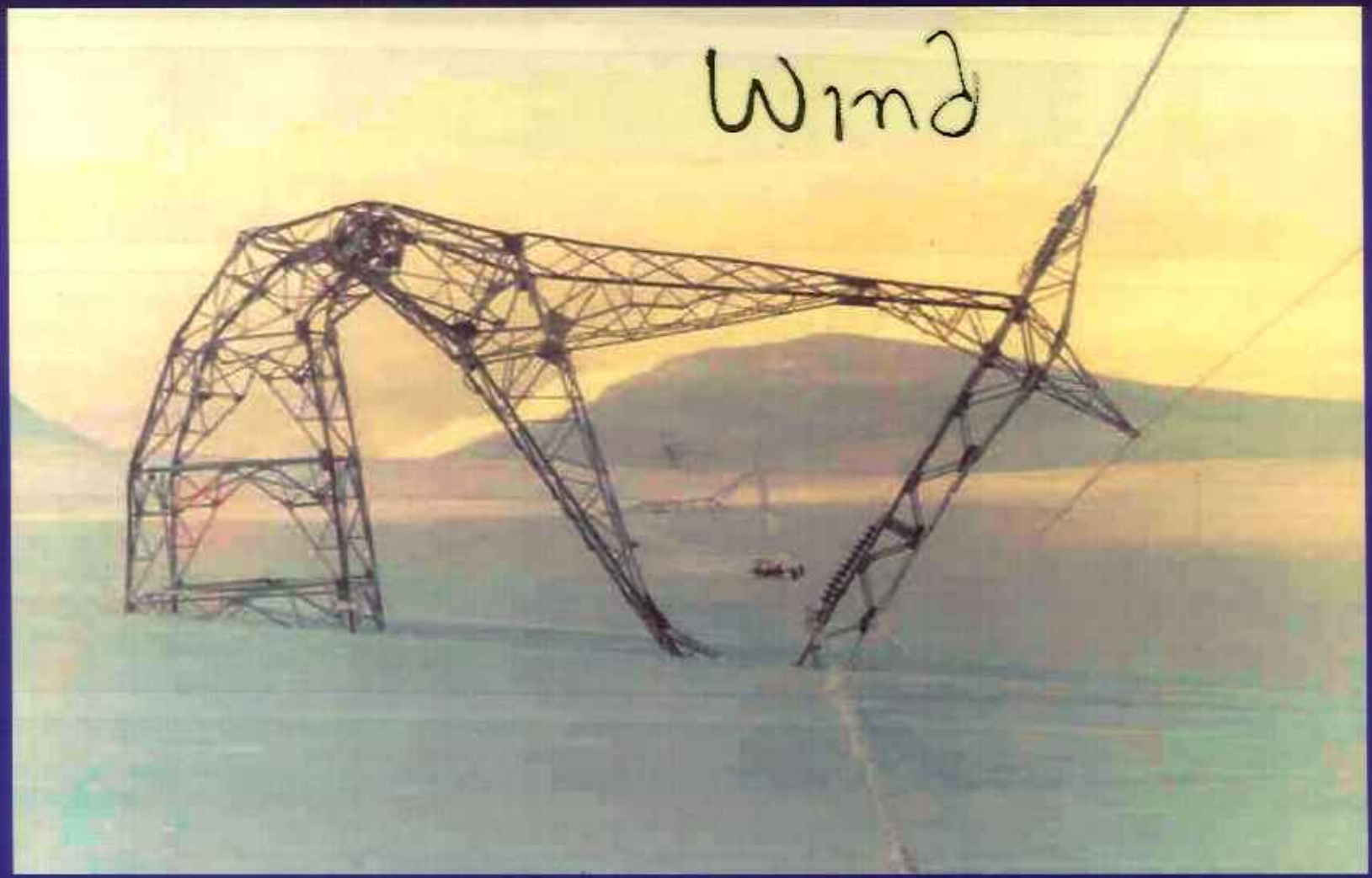
Transmission
problems


Lightning

Dangerous downed power lines in New Orleans from Katrina

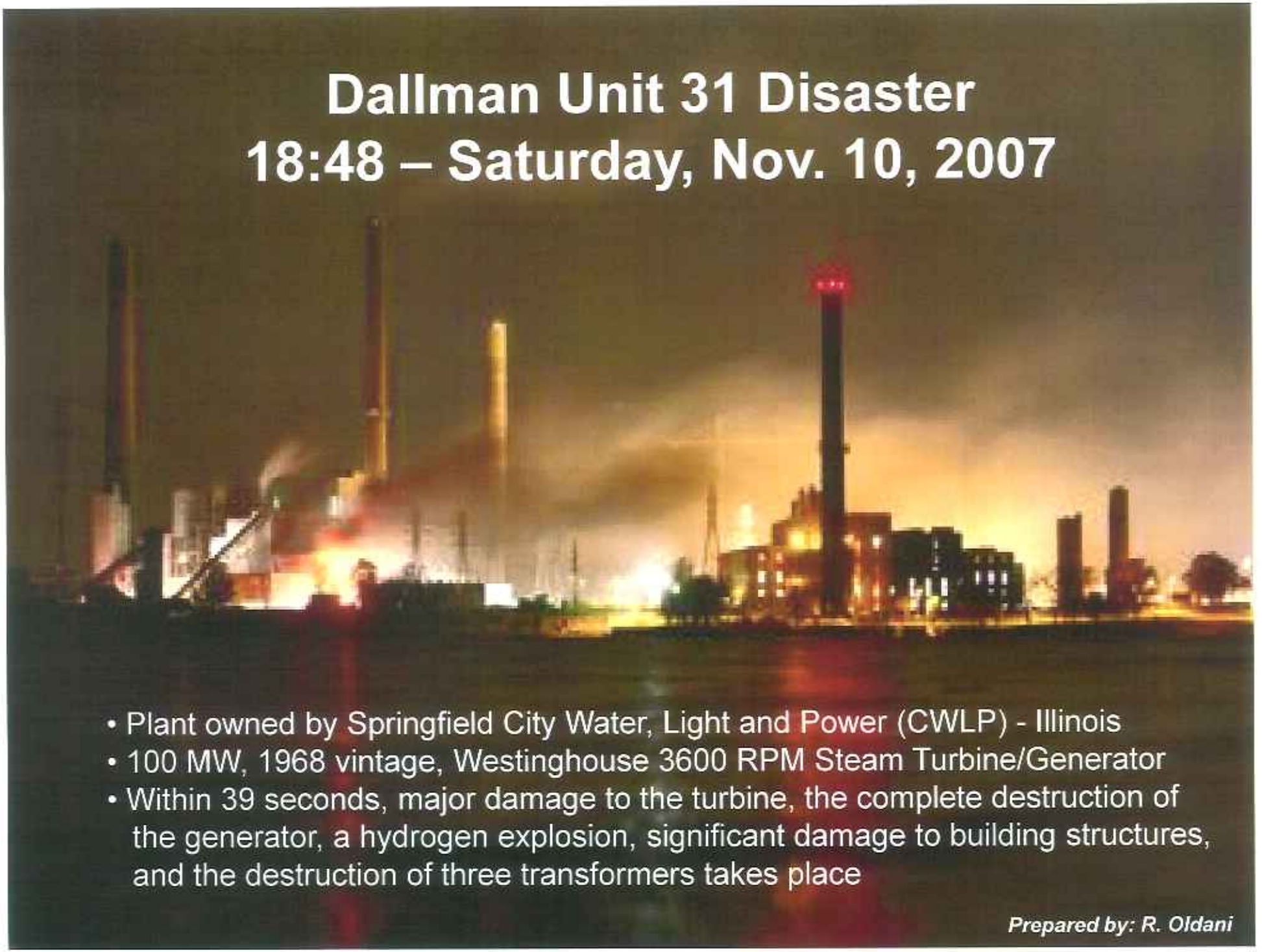
Snow




Wind

"And then one day the grid went down and never came back up."

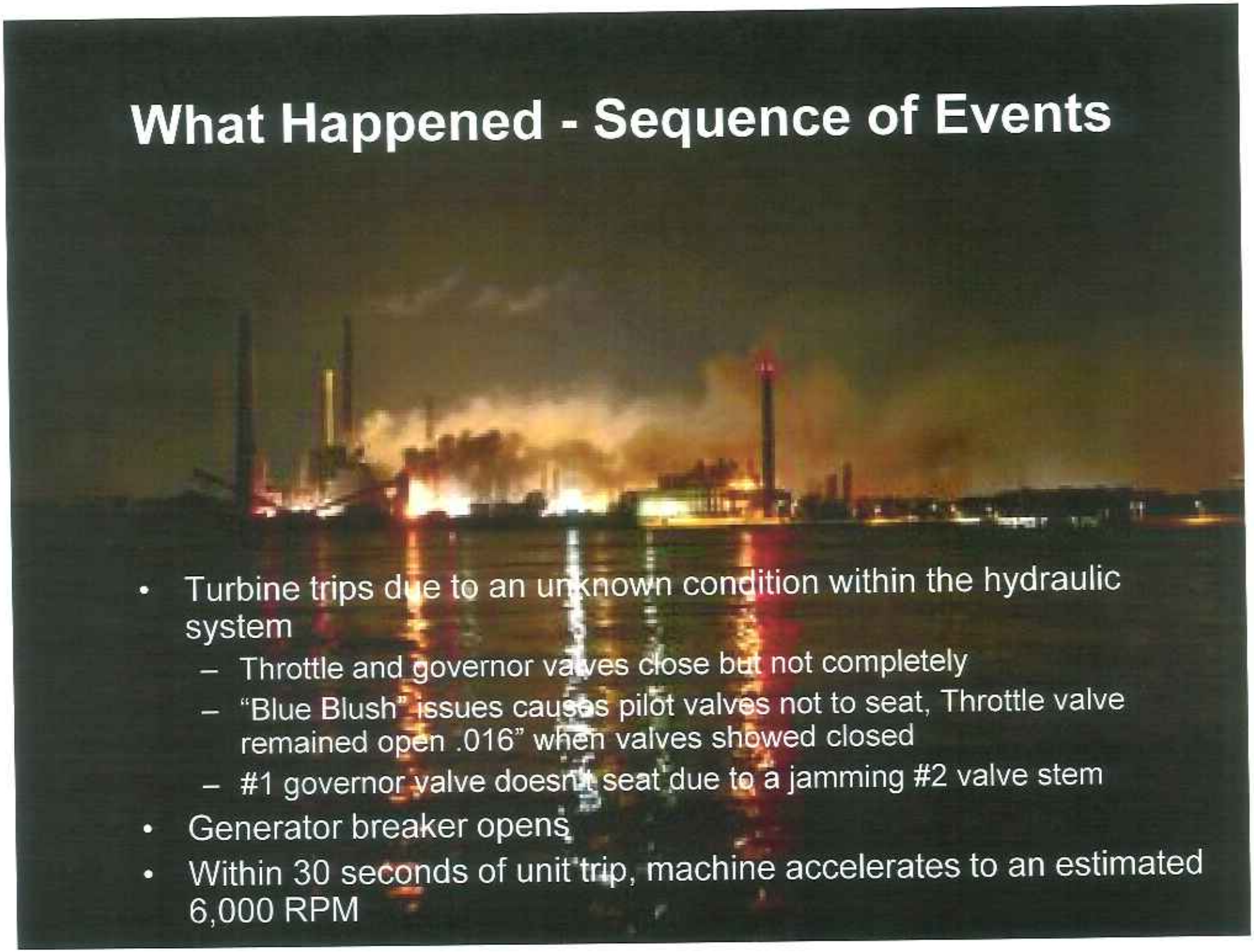
Dallman Unit 31 Disaster
18:48 – Saturday, Nov. 10, 2007



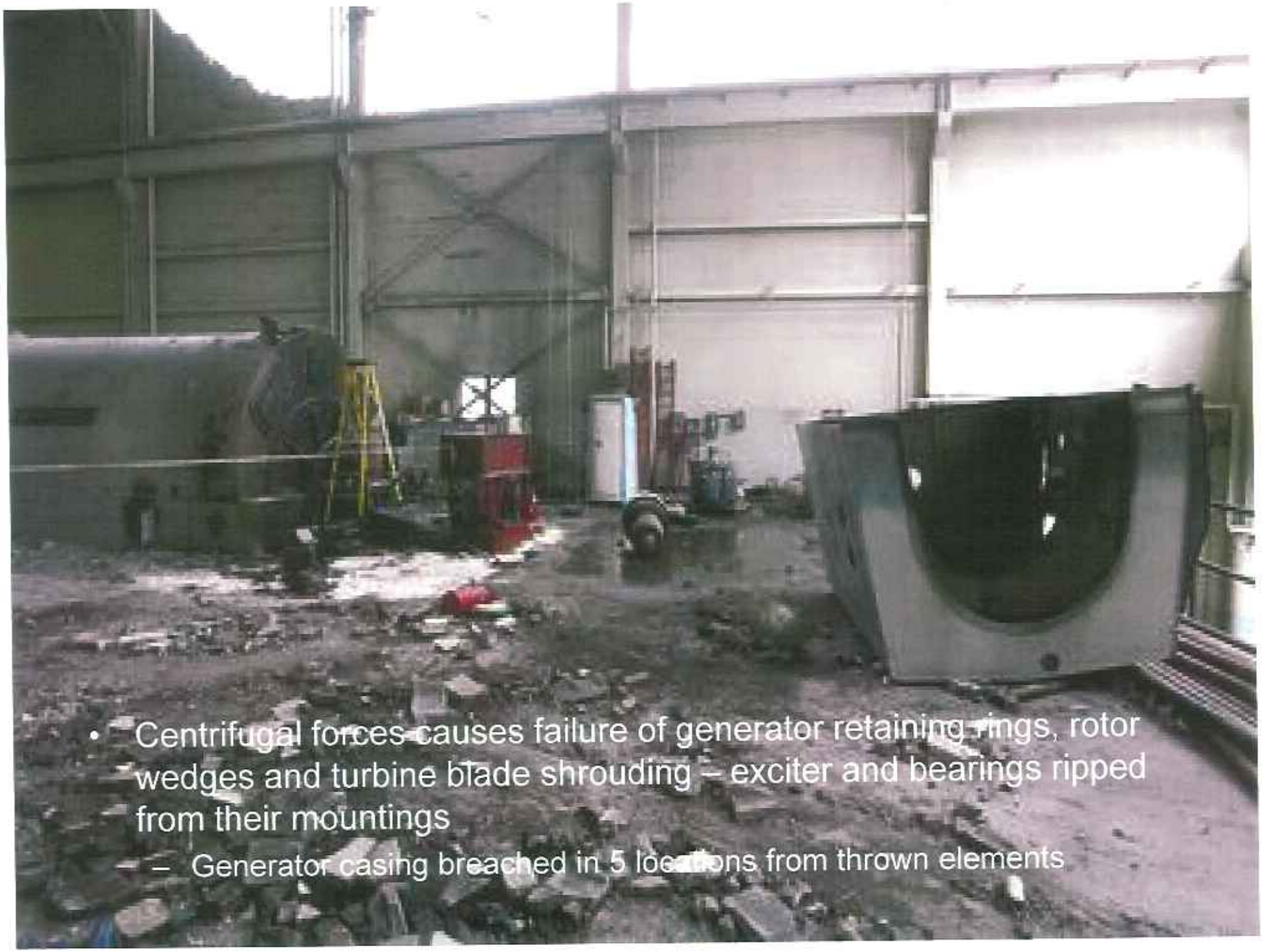
- Plant owned by Springfield City Water, Light and Power (CWLP) - Illinois
- 100 MW, 1968 vintage, Westinghouse 3600 RPM Steam Turbine/Generator
- Within 39 seconds, major damage to the turbine, the complete destruction of the generator, a hydrogen explosion, significant damage to building structures, and the destruction of three transformers takes place

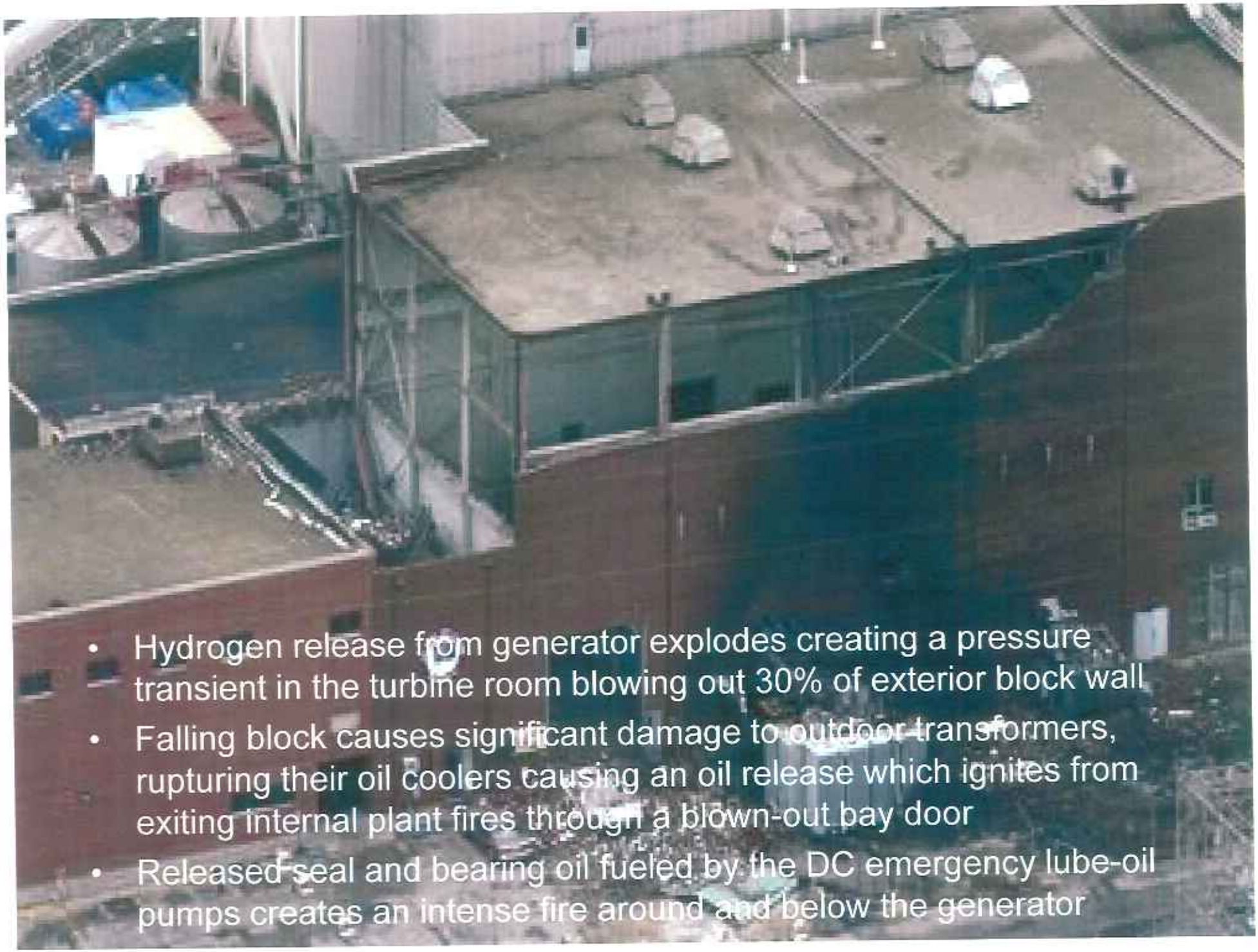
Prepared by: R. Oldani

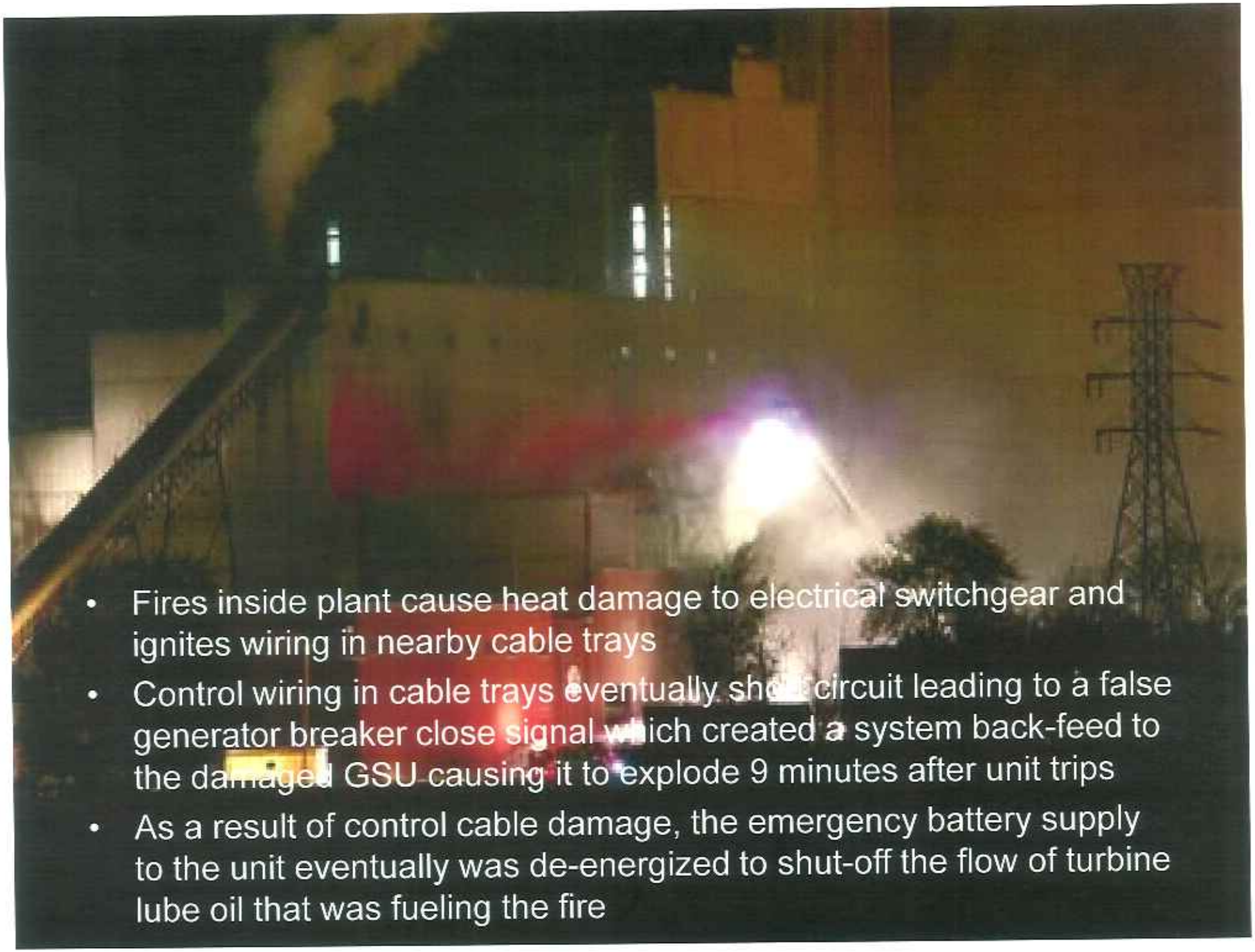
What Happened - Sequence of Events



- Turbine trips due to an unknown condition within the hydraulic system
  - Throttle and governor valves close but not completely
  - "Blue Blush" issues causes pilot valves not to seat, Throttle valve remained open .016" when valves showed closed
  - #1 governor valve doesn't seat due to a jamming #2 valve stem
- Generator breaker opens
- Within 30 seconds of unit trip, machine accelerates to an estimated 6,000 RPM


• Centrifugal forces causes failure of generator retaining rings, rotor wedges and turbine blade shrouding – exciter and bearings ripped from their mountings
– Generator casing breached in 5 locations from thrown elements


• Hydrogen release from generator explodes creating a pressure transient in the turbine room blowing out 30% of exterior block wall
• Falling block causes significant damage to outdoor transformers, rupturing their oil coolers causing an oil release which ignites from exiting internal plant fires through a blown-out bay door
• Released seal and bearing oil fueled by the DC emergency lube-oil pumps creates an intense fire around and below the generator


• Fires inside plant cause heat damage to electrical switchgear and ignites wiring in nearby cable trays
• Control wiring in cable trays eventually short circuit leading to a false generator breaker close signal which created a system back-feed to the damaged GSU causing it to explode 9 minutes after unit trips
• As a result of control cable damage, the emergency battery supply to the unit eventually was de-energized to shut-off the flow of turbine lube oil that was fueling the fire

Additional Findings/Salient Conclusions

Taken from Engineer's Report

- Records indicated that the throttle valves had a propensity to stick, particularly during start-up
- Wear steps had been observed previously on the stems of the governor valves
- A deep wear step on one of the valve stems appears to have jammed against the edge of the bar, contributing to the wedging of the valve lift bar, thereby preventing one or more valves from lowering into their respective valve seats
- Historical review of adjacent unit data shows coincident steam flow and speed increase of turbine after a full-load unit trip
- The practice of using hydraulic jacks and pinch bars on the throttles valves during start-up to dislodge stuck valves needs to be eliminated

Notable Physical Change Recommendations

Taken from CWLP Report

- Review relay protection schemes and add sequential tripping for the unit
- Convert unit to full EHC control of throttle and governor valves, include precise LVDT position indicators
- Research reducing pilot valve stroke and change material to non-blushing steel
- Get an engineered solution to governor valve shouldering, could include hardened steel bushings and machining a radius to the shoulders of the valve guides

Notable Procedural Change Recommendations

Taken from CWLP Report

- Start-up procedures have been rewritten and includes a positive verification of Throttle Valve closure at 600 RPM prior to placing unit on-line
- Over-speed trip test procedure has been rewritten and implemented weekly
- A weekly PM work order for exercising the Throttle Valves has been re-emphasized
- Disassemble, inspect and rebuild throttle Valves each year under OEM supervision
- Disassemble, inspect and rebuild Governor Valves every two years under OEM supervision
- Disassemble, inspect and rebuild Non-Return Valves every three years
- Recommend developing and implementing a "Preventive Maintenance Work Order Deviation Report" for all PMs not performed
- Develop QA/QC program for unit and equipment start-up and shut-downs
- Implement a regular audit to verify compliance with critical tests and PM work orders and procedures

Key Takeaways for DTE

- Don't tol[illegible] sticking turbine valve problems, aggressively deal with [illegible]
- Religiously [illegible] turbine valve tests to exercise valves and detect incipie[illegible] problems
- Check our unit operating procedures to s[illegible]re have a defined understanding on how to cut emerge[illegible] power to oil pumps if control circuitry is disabled due to fire
- Question delaying turbine valve maintenance inspections
- Follow emerging turbine valve and stem designs, nan[illegible]coating (EPRI) or other types of coating such as chromium carbide to manage "blue blush" environments
- Don't tolerate questionable "reverse current" relay operation, aggressively remedy unreliability issues
  - Trenton 8 relay reliability?
  - Harbor Beach recently converted to reverse current tripping scheme, however time delayed computer logic backup generator breaker trip needs assessment
  - River Rouge tripping scheme currently undergoing a design change review to trip on reverse current

SCAN

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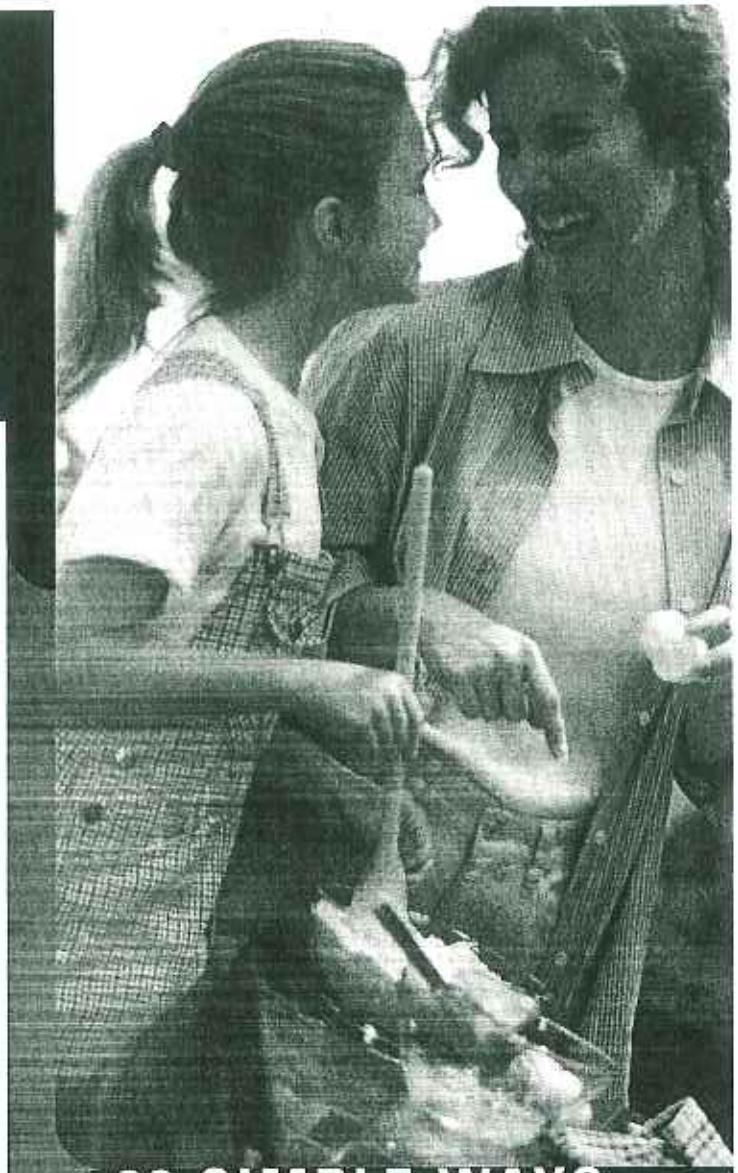


60 SIMPLE WAYS

TO SAVE MONEY
ON YOUR ENERGY BILL

Xcel Energy®

Table of Contents:

Save Energy and Money 1

Your Household Energy Use 1

Easiest Ways to Save Money and Energy 2

Energy-Saving Investments For Your Home 3

60 Money and Energy-Saving Tips 4

- Heating 4
- Cooling 6
- Plumbing/Water Heating 8
- Kitchen Appliances 10
  - Refrigerator/Freezer 10
  - Oven/Range/Microwave 11
  - Dishwasher 12
- Clothes Washer/Dryer 13
- Lighting 14
- Weatherizing Your Home 15

Appliances: Energy-Savings Chart 16

Heating and Cooling: Energy-Savings Chart 18

Cost Assumptions Used for This Guide 20

Questions? Web sites and Other Resources 21

SAVE ENERGY AND MONEY

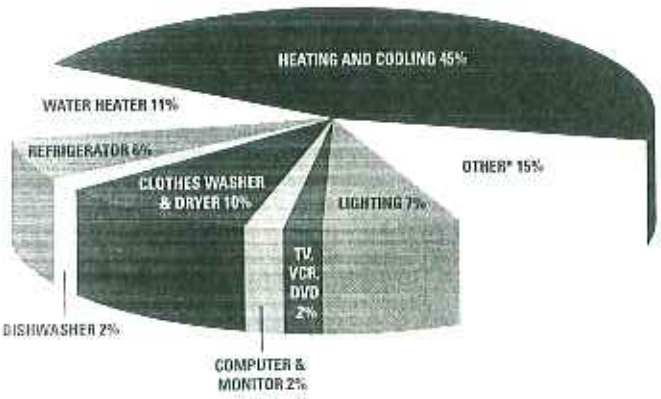
Using less energy helps you save money, conserve natural resources and reduce power plant emissions. We'll all benefit from a more energy-efficient world and a cleaner environment.

Reducing energy use can be as simple as turning off lights when you leave a room. How you use and choose appliances has an even larger impact on your energy use and your energy bill. This guide includes:

- A chart that shows you the general cost-saving opportunities when using energy-efficient appliances.
- A climate zone chart that helps you estimate the energy-savings opportunities for heating and cooling your home when you adjust temperature settings on standard and energy-efficient furnaces and air conditioners.

Your Household Energy Use

Heating and cooling account for nearly half of the typical home's energy usage. This booklet explains how changes you make in these and many other areas can add up to large energy savings.



* This category represents an array of household appliances, including ranges, ovens, microwave ovens and other small appliances. Individually, these appliances account for no more than 2 percent of typical household energy.

Source: Energy Star and U.S. Department of Energy, 2004.

EASIEST WAYS TO SAVE MONEY AND ENERGY

You may already be doing things to save energy around your home. Here are some simple and inexpensive ways to help you save even more.

- Close your fireplace damper when the fireplace isn't in use. (tip 2, page 4)
- Use ventilation fans only as long as necessary. (tip 7, page 5)
- Lower your thermostat setting during winter to 68 degrees. (tip 10, page 5)
- Raise your thermostat setting during summer to 78 degrees. (tip 16, page 6)
- Repair leaky faucets, especially those supplying hot water. (tip 22, page 8)
- Install low-flow showerheads. (tip 23, page 8)
- Clean your refrigerator coils. (tip 30, page 10)
- Run the dishwasher only when it's full. (tip 42, page 12)
- Wash clothes in cold water. (tip 47, page 13)
- Raise and lower window coverings to allow heat in during cold weather and keep heat out during hot weather. (tip 58, page 15)

ENERGY-SAVING INVESTMENTS FOR YOUR HOME

Here are important energy-saving ways to increase the value of your home and provide significant energy savings over the long-term.

- Have your furnace regularly maintained by a professional. (tip 1, page 4)
- Install a programmable thermostat to automatically adjust your home's temperature with your daily routine. (tip 4, page 4)
- Install or add attic insulation if existing insulation is less than six inches thick. (tip 11, page 5)
- Use a whole house fan or attic fan for cooling on warm nights. (tip 14, page 6)
- Install ceiling fans for air circulation. (tip 15, page 6)
- When replacing or upgrading your refrigerator or other kitchen appliances, choose the most efficient model you can afford. (tip 34, page 10)
- Install dimmer switches and motion sensors to control lights when you are away. (tip 54, page 14)
- Change to compact fluorescent light bulbs, especially for lights you use frequently and for long periods of time. (tip 57, page 14)
- Seal window leaks around your home. (tip 59, page 15)
- Caulk and weather strip around pipes, ducts and vents. (tip 60, page 15)

60 MONEY AND ENERGY-SAVING TIPS

Heating

1. Have Your Furnace Regularly Maintained By A Professional

Regular furnace maintenance can reduce energy costs between $18 and $60 each winter with an 80 percent efficient furnace in a 1,600-square-foot home.

2. Keep Your Fireplace Damper Closed

Keep your fireplace damper closed when not in use to prevent up to 5 percent heat loss. When using the fireplace, turn down your thermostat and open a window near the fireplace to prevent warm air from being pulled from other areas of your house.

3. Seal Duct Leaks

Seal leaky ducts with mastic, metal-backed tape or aerosol sealant. This will reduce heat loss when your furnace is on and may last longer than duct tape.

4. Use A Programmable Thermostat

This device can save as much as 20 percent on heating costs by automatically turning your heating system up or down to coincide with your daily routine. For example, set your thermostat to 60 degrees for the night and while you are away.

5. Keep Your Furnace or Heat Pump Filter Clean

Dirty filters reduce airflow, making your equipment work harder and use more energy. Replace your furnace filter monthly during the heating season, and you could reduce heating costs by 5 percent.

6. Open Inside Doors To Improve Air Circulation

Keep the doors inside your home open to improve air circulation and the efficiency of your heating and cooling systems.

7. Use Ventilation Fans Only As Needed

Don't forget to turn off a kitchen or bathroom ventilation fan. In just an hour, all the heated air in your home can be drawn out through an exhaust vent.

8. Use Passive Solar Heating On Sunny Days

Open drapes on south-facing windows when it is sunny. At night, close drapes to retain heat. Close drapes to provide insulation where windows receive no direct sunlight. Up to 15 percent of your heat can escape through unprotected windows.

9. Choose High-Efficiency Furnace And Boiler Systems

The furnaces with the highest efficiency ratings, 90 percent or more, use approximately 15 percent less energy than other models. You could save as much as $100 each heating season with a high-efficiency natural gas furnace. See chart on page 18.

10. Lower Your Thermostat Setting

Reduce indoor thermostat temperature from 72 to 68 degrees during the heating season to save 5 percent on heating costs.

11. Ensure Your Home Is Properly Insulated

Poor or no insulation means losing up to 25 percent of your heating energy. Your attic needs at least six inches of insulation. Insulate crawl spaces, walls, floors and heating ducts to save money and increase your comfort.

Cooling

12. Plant Trees For Shade

Deciduous trees – those that produce leaves in the spring and lose them in the fall – shade your house from the sun during summer and let the sun warm your house in winter. Shading your home could save up to 8 percent on cooling costs.

13. Change Your Air Conditioning Filter

Clean or replace your central air conditioner's (AC) filter monthly during the cooling season to improve efficiency and the life of your AC.

14. Consider A Whole House Or Attic Fan

Through your open windows, a whole house or attic fan draws cool nighttime air in and forces out hot air that built up during the day. These fans work best in drier climates.

15. Use Ceiling Fans To Cool Your House

The most efficient ceiling fans cost as little as 30-cents a month if used eight hours a day. A window air conditioner can cost 50 times as much as a fan.

Ceiling fans will keep the air moving and allow you to keep the thermostat setting higher because moving air feels cooler.

16. Raise Your Thermostat Setting

You can save approximately $100 in a summer by raising your thermostat's temperature from 72 to 78 degrees.

17. Open Windows On Cool Nights

On cool days and nights, turn off your air conditioner and open your windows. Don't open windows when the outside temperature is warmer than the inside of your house.

18. Keep Air Conditioner Coils Dust-Free

Keep the coils of your central air conditioner and/or window AC unit free of dust and dirt to increase efficiency and lifetime use. Coils are usually on the back of window AC units.

19. Match The Output Of Your AC To The Space You Cool

When you buy an air conditioner – central air or a window unit – make sure the output of the system is right for the size of the room or the size of your house to ensure efficiency and comfort. Check the manufacturer's recommendations or consult with a reputable AC vendor in advance to ensure proper sizing.

20. Use a Programmable Thermostat

This device can save as much as 12 percent on cooling costs by automatically turning your cooling system up or down to coincide with your daily routine. For example, set your temperature to 85 degrees when you're away.

21. Provide Shading For Your Air Conditioning Condenser

Your central air conditioner's condenser works more efficiently at cooler temperatures. Provide shade around your air conditioner to reduce your cooling costs by nearly 3 percent.

Plumbing/Water Heating

22. Repair Leaky Faucets

One drop per second from a leaky faucet wastes up to 400 gallons of water a year. Not only is water being wasted, but so is the energy used to heat the water.

23. Choose Low-Flow Showerheads And Faucets

Low-flow showerheads and faucets can reduce water consumption by as much as 10 percent. You also save on the energy used to heat water and won't notice any difference in water pressure. With four people in a home, you can save as much as 15,000 gallons of water in a year when you install these water-saving devices.

24. Insulate Water Heater And Hot Water Pipes

If your water heater and hot water pipes are warm to the touch, insulation could reduce heat loss and water heating costs.

25. Set Your Water Heater At 120 Degrees

Overheating your water, beyond 120 degrees, can be wasteful and unsafe. By lowering your water temperature to 120 degrees or less, you can save up to $25 annually if you use an electric water heater or $18 annually if you use a gas water heater.

26. Drain Sediment From Your Water Heater Tank

Sediment, a by-product of water heating, obstructs the transfer of heat. Draining sediment every six months improves water heater efficiency and reduces energy usage.

27. Take A Short Shower Instead Of A Bath

Every minute you cut from your shower time saves three gallons of water and the energy used to heat the water. You'll save hundreds of gallons of water a year taking showers over baths, and you'll save the energy to heat all that wasted water.

28. Turn Your Water Heater Down When You Leave Town

Going on vacation? Turn your water heater down to the lowest setting. Before you go, leave yourself a reminder note to turn your water heater back up when you return.

29. Choose A High-Efficiency Water Heater

High-efficiency water heaters can be more expensive than standard models. However, the payback period for a natural gas water heater is less than 2.5 years on a 12-year lifespan. An electric water heater has a 10-year payback on a 25-year life. See chart on page 16.

Kitchen Appliances

Refrigerator/Freezer

30. Clean Your Refrigerator Coils

Once a year, pull out your refrigerator and clean or dust the coils located on the back of the refrigerator. Clean coils help the compressor cool faster and run less frequently, which extends the life of your refrigerator and reduces energy use.

31. Cover Refrigerated Foods

Covered foods reduce power consumption by limiting moisture evaporation into the air. Moist air takes more energy to cool than dry air, forcing the compressor to work harder. Plus, your refrigerator will smell better.

32. Set Your Refrigerator At The Right Temperature

Your refrigerator temperature should be set between 34 and 37 degrees and your freezer at 5 degrees. Not only are these the safest temperatures for food storage, but most refrigerators are manufactured to operate most efficiently at these settings.

33. Buy The Smallest Freezer You'll Need

Because a freezer operates most efficiently when full, buy the smallest freezer you think you will need. Clean the coils on the back once every year.

34. Consider A High-Efficiency Refrigerator

When replacing your refrigerator, choose a high-efficiency one. And think about the impact of certain features on your purchase.

For example, top-freezer models use 7 percent to 13 percent less energy and are usually less expensive than side-by-side models. Over the average 19-year lifespan of a refrigerator, you can save approximately $320 with a top-freezer style.

Automatic icemakers and through-the-door dispensers increase energy use by 14 percent to 20 percent.

Oven/Range/Microwave

35. Choose A Gas Range With Pilotless Ignition

Pilotless ignition eliminates the need for the pilot light to burn continuously, reducing your natural gas usage.

36. Keep Oven Door Closed

Every time you open the oven door, the oven temperature can drop 25 degrees. Use the oven light or a timer to avoid wasting energy.

37. Defrost Food Before Cooking And Pre-Heat Only For Baking

Save 30 percent to 50 percent on cooking costs by defrosting your food before cooking—your food will cook faster. Pre-heating is important for baking, but if you're re-heating a casserole or cooking a roast, pre-heating isn't necessary.

38. Use Lids And Turn Off Electric Burners Early

Use lids to trap steam and help food cook faster. If you're cooking with an electric range, you can turn off the burners a few minutes early because the burners retain heat.

39. Retain Oven Heat With A Good Door Seal

Gently clean the seal on your oven door with kitchen degreaser to ensure that it retains the maximum amount of heat when baking.

40. Use Small Appliances

Use an electric skillet, broiler oven, or toaster oven instead of your conventional oven for cooking and baking small quantities. These may use just half the energy.

41. Use Heat-Producing Appliances When It's Cooler

To keep your home cooler during summer, use heat-producing appliances at cooler times of the day, such as early morning and at night. On warm days, instead of using your range or oven, use your toaster oven, microwave and outdoor grill to keep your home cool and use less energy.

Dishwasher

42. Run Your Dishwasher Only When It's Full

Get in the habit of running your dishwasher only when it's full to maximize energy use.

43. Scrape, Don't Rinse Your Dishes

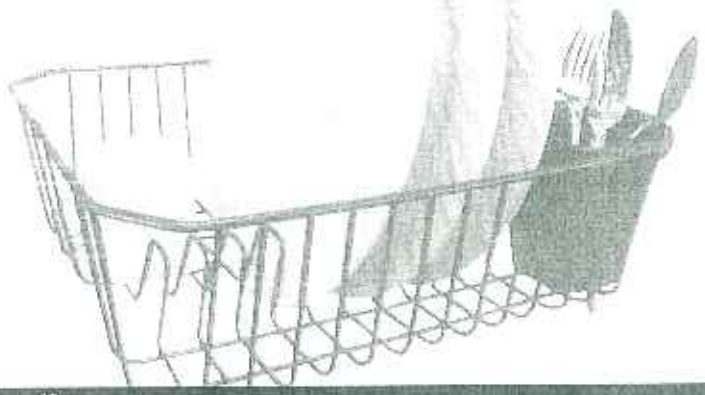
Scrape your dishes instead of rinsing to save water and the energy needed to heat the water.

44. Air-Dry Your Dishes, Even In The Dishwasher

Air dry the dishes or use the unit's energy-saving features. Avoid using the heat-dry, rinse-hold and pre-rinse features.

45. Choose A High-Efficiency Dishwasher

High-efficiency dishwashers, such as those with internal water heaters and load sensors, use 25 percent less energy than conventional models. You can save up to $30 a year by replacing a 10-year-old dishwasher with a high-efficiency model.



Clothes Washer/Dryer

46. Run Full Loads Of Laundry And Shorten Wash Cycles

Run full loads of laundry to maximize energy and water use. In addition, most loads require only an eight- to 12-minute wash cycle. Use your custom load feature to reduce wash time.

47. Wash Clothes In The Coolest Water Possible

About 80 percent of the cost to run your washer is used for heating the water. Except for all-white loads, there is little benefit to washing with hot water.

48. Dry Loads Back-to-Back

Since your dryer retains heat, dry several loads in a row. You can reduce the heat level on the last load or two. Dry your lightweight items together, using a lower heat setting for less time.

49. Clean Your Dryer Filter And Exhaust Vent

Regularly clean out your dryer filter and exhaust vent. When they become clogged with lint, your dryer works harder and uses more energy.

50. Use The Auto-Dry Feature

Newer dryers have moisture sensors to determine when clothes are dry. Use this feature to avoid over-drying and reduce dry time.

51. Choose A Natural Gas Dryer

A natural gas dryer operates at half the cost of an electric dryer, and could save a household of four more than $50 a year.

52. Choose A High-Efficiency Clothes Washer And Dryer

High-efficiency washers use half the water of standard models, which can be as much as 7,500 gallons a year. High-efficiency clothes dryers can save up to 30 percent in energy use over a standard model.

Lighting

53. Turn Off Lights When You Leave A Room

Every time you turn off lights when they're not needed, you're saving energy and money. Keeping one 75-watt bulb off for one hour per day saves $2.15 per year.

54. Install Dimmers And Motion Sensors Where Possible

Dimmer switches can increase bulb life up to 20 times longer if dimmed to half the brightness. Motion sensors give you light when you need it.

55. Use Three-Way Bulbs To Increase Light And Reduce Energy

Three-way bulbs reduce energy use by providing the right amount of light where it's needed, instead of overlighting with a single high-wattage bulb.

56. Install Motion Detector Lights For Outdoor Lighting

Motion detectors put light where you want it, for brief periods of time, to provide safety and security for your property.

57. Install Compact Fluorescent (CFL) Bulbs Where You Can

Over the life of one CFL bulb you will save approximately $25. Just a handful around the house, and you could notice a difference in your energy bills. They cost a bit more, but you'll change them less often, and they produce little or no heat.

Weatherizing Your Home

58. Install Window Coverings To Insulate Your Home

During winter days, open curtains, blinds and shades to heat your home with solar power. Close them at night to retain that heat.

In summer, do the opposite: close curtains and shades during the day to retain cool air and reduce the burden on your air conditioner.

59. Seal Household Window Drafts

Older homes, in particular, can benefit during winter from covering windows with plastic film. Home improvement stores carry these easy-to-install window-sealing kits. You'll block out drafts and could save more than $40 on your energy bill in one heating season.

60. Control Air Leaks In Your Home

Plug gaps around pipes, ducts and vents that go through walls to prevent losing heated air and having cold air drawn in to replace it. Caulk or seal plumbing and wiring holes at ceiling level. Add weather-stripping to doors and windows for the most cost-efficient way to protect your home.

APPLIANCES: ENERGY-SAVINGS CHART

Use the chart below to see generally how much energy is used and how much it costs to operate household appliances. These costs are estimates, please see assumptions listed on page 20.

***Standard vs. Efficient Appliances**

The chart below compares energy efficient appliances to standard, non-energy efficient appliances. Purchasing high-efficiency appliances, often certified by ENERGY STAR®, can save you 30 percent or more on your energy costs. ENERGY STAR® appliances meet the government's energy efficiency rating. See www.energystar.gov.

Electric/Natural Gas Appliance Use and Operating Costs Appliances	Monthly Usage Standard Model*	Monthly Cost Standard Model*	Monthly Usage Efficient Model*	Monthly Cost Efficient Model*
Electric Water Heater (household of four, 90 gal/day)	488 kWh	$38.07	477 kWh	$37.24
Natural Gas Water Heater (household of four, 90 gal/day)	26 therms	$20.28	24 therms	$18.64
Refrigerator/Freezer (25 cubic feet side-by-side w/ icemaker)	99 kWh	$7.72	54 kWh	$4.21
Refrigerator/Freezer (20 cubic feet top/bottom)	76 kWh	$5.95	42 kWh	$3.24
Freezer (14 cubic feet frost-free)	54 kWh	$4.22	n/a	n/a
Dishwasher (home w/ electric water heater average 18 washes per month)	48 kWh	$3.75	36 kWh	$2.81
Dishwasher (home w/ natural gas water heater average 18 washes per month)	20 kWh 1.5 therms	$2.68	18 kWh 1 therm	$2.10
Electric Range (typical monthly usage)	161 kWh	$12.56	n/a	n/a
Natural Gas Range (typical monthly usage)	6 therms	$4.29	n/a	n/a
Microwave (@ 15 min/day)	11 kWh	$0.88	n/a	n/a
Toaster (@ five min/day)	4 kWh	$0.31	n/a	n/a
Clothes Washer (home w/ electric water heater average 33 washes per month)	96 kWh	$7.49	51 kWh	$3.98
Clothes Washer (home w/ natural gas water heater average 33 washes per month)	8 kWh 4.5 therms	$4.05	8 kWh 2 therms	$2.29
Electric Clothes Dryer (25 loads per month, one hour each)	106 kWh	$8.27	n/a	n/a
Natural Gas Clothes Dryer (25 loads per month, one hour each)	7 kWh 4 therms	$3.67	n/a	n/a
Lighting - 20-watt compact fluorescent (one month @ eight hours/day)	5 kWh	$0.39	n/a	n/a
Lighting - 75-watt incandescent (one month @ eight hours/day)	18 kWh	$1.40	n/a	n/a
Electric Space Heater (hourly usage, 80 sq ft space)	2 kWh	$0.12	n/a	n/a
Natural Gas Garage Space Heater (hourly usage, 400 sq ft)	.25 therms	$0.20	n/a	n/a
Natural Gas Fireplace (hourly usage)	.26 therms	$0.20	n/a	n/a
Natural Gas Grill (hourly usage)	.35 therms	$0.27	n/a	n/a

HEATING AND COOLING: ENERGY-SAVINGS CHART

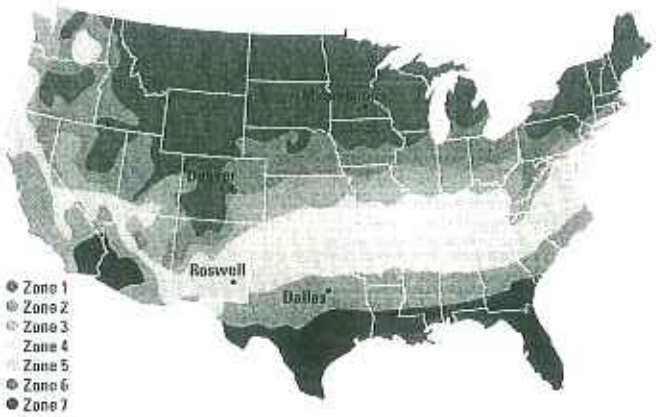
You can quickly and easily reduce your monthly energy costs by lowering your furnace temperature in the winter and raising your cooling temperature in the summer. To reduce your energy costs even more, replace old furnaces and air conditioners with energy-efficient (EE) equipment.

Use the charts below to estimate about how much you are paying for heating and cooling costs now and how much you could save by simply adjusting your thermostat. The charts represent monthly costs for operating a furnace in the coldest month of winter and an air conditioner in the warmest month of summer, based on the climate zone where you live.

Identify Your Zone And Potential Savings:

Step 1. Use the map to find your climate zone.

Step 2. Use the chart below to find energy-savings opportunities in your home.



Heating: Turn it Down to Save Money

	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5	
	therms Used	Operating Cost	therms Used	Operating Cost	therms Used	Operating Cost	therms Used	Operating Cost	therms Used	Operating Cost
Standard Furnace set at 72°, 80% AFUE	334	$260	314	$245	185	$144	130	$101	102	$79
EE Furnace set at 72°, 90% AFUE	297	$231	279	$218	164	$128	116	$90	90	$71
Standard Furnace set at 68°, 80% AFUE	286	$223	254	$198	145	$113	95	$74	80	$62
EE Furnace set at 68°, 90% AFUE	254	$198	226	$176	129	$101	84	$66	71	$55

Cooling: Turn it Up to Save Money

	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5	
	kWh Used	Operating Cost	kWh Used	Operating Cost	kWh Used	Operating Cost	kWh Used	Operating Cost	kWh Used	Operating Cost
Standard Air Conditioner set at 72°, 10 SEER	953	$74	871	$68	1153	$90	1012	$79	2456	$192
EE Air Conditioner set at 72°, 13 SEER	794	$62	725	$57	961	$75	843	$66	2046	$160
Standard Air Conditioner set at 78°, 10 SEER	518	$40	447	$35	753	$59	671	$52	1604	$125
EE Air Conditioner set at 78°, 13 SEER	431	$34	373	$29	627	$49	559	$44	1336	$104

COST ASSUMPTIONS USED FOR THIS GUIDE

- Natural Gas: $0.78 per therm Propane: $1.53 per gallon
  Fuel Oil: $1.60 per gallon Electricity: $0.078 per kWh
- The price of natural gas used in this brochure reflects an Xcel Energy customer's price including distribution charges and the cost of gas that the company purchased for service.
- The price of propane and fuel oil reflects a price which has been adjusted for seasonal differences that does not include taxes, local fees, customer charges or any other additional fees above the cost of the fuel and distribution.
- The price of electricity reflects an Xcel Energy customer's price, excluding state taxes, municipal taxes or other local fees.
- Energy savings are based on an average kilowatt-hour cost across Xcel Energy's 10-state service area. Energy savings for natural gas also have been adjusted to an average across Xcel Energy's 10-state service area.
- Appliance information represents an array of household appliances, including ranges, ovens, microwave ovens and other small appliances. Individually, these appliances account for no more than 2% of typical household energy.

Assumptions for "Heating and Cooling: Energy-Savings Chart" page 18:

- Costs and usage represent a home of typical architecture and construction per zone.
- Representative cites: Minneapolis, MN; Denver, CO; Roswell, NM; and Dallas, TX.
- Monthly heating values are for January, generally the coldest month of the year.
- Monthly cooling values are for July, generally the warmest month of the year.
- Zones 6 and 7 are not included in these tables because they are not part of Xcel Energy's service area.
- AFUE (Annual Fuel Utilization Efficiency) rating shows the furnace unit's energy efficiency. The higher the number, 90% for example, means it's more efficient than furnaces with a lower percentage.
- SEER (Seasonal Energy Efficiency Ratio) measures an air conditioner's cooling efficiency. The higher the SEER number, the more efficient the unit.

QUESTIONS? WEB SITES AND OTHER RESOURCES

Call our Customer Care Center at **1-800-895-4999** with any energy-related questions.

In addition to this brochure, we have **FREE online resources** such as the Home Energy Analyzer, brought to you by *InfoSmart from Xcel Energy℠*. It's right on our Web site and helps you evaluate your home's energy-efficiency potential. You input details such as number of rooms and types of appliances, and it gives you lots of specific ways to save energy and money.

Go to **xcelenergy.com/infosmart** to explore *InfoSmart from Xcel Energy℠* resources such as the Home Energy Analyzer and these other energy-saving tools:

- Energy Calculators
- ENERGYsmart University
- ENERGYsmart Library

Or visit **xcelenergy.com/energysavings** to access these resources as well as additional brochures and video content on saving energy and money in and around your home.

Other sources used in preparing this guide include:

- The Environmental Protection Agency | www.epa.gov
- The ENERGY STAR® program | www.energystar.gov
- The U.S. Department of Energy | www.doe.gov