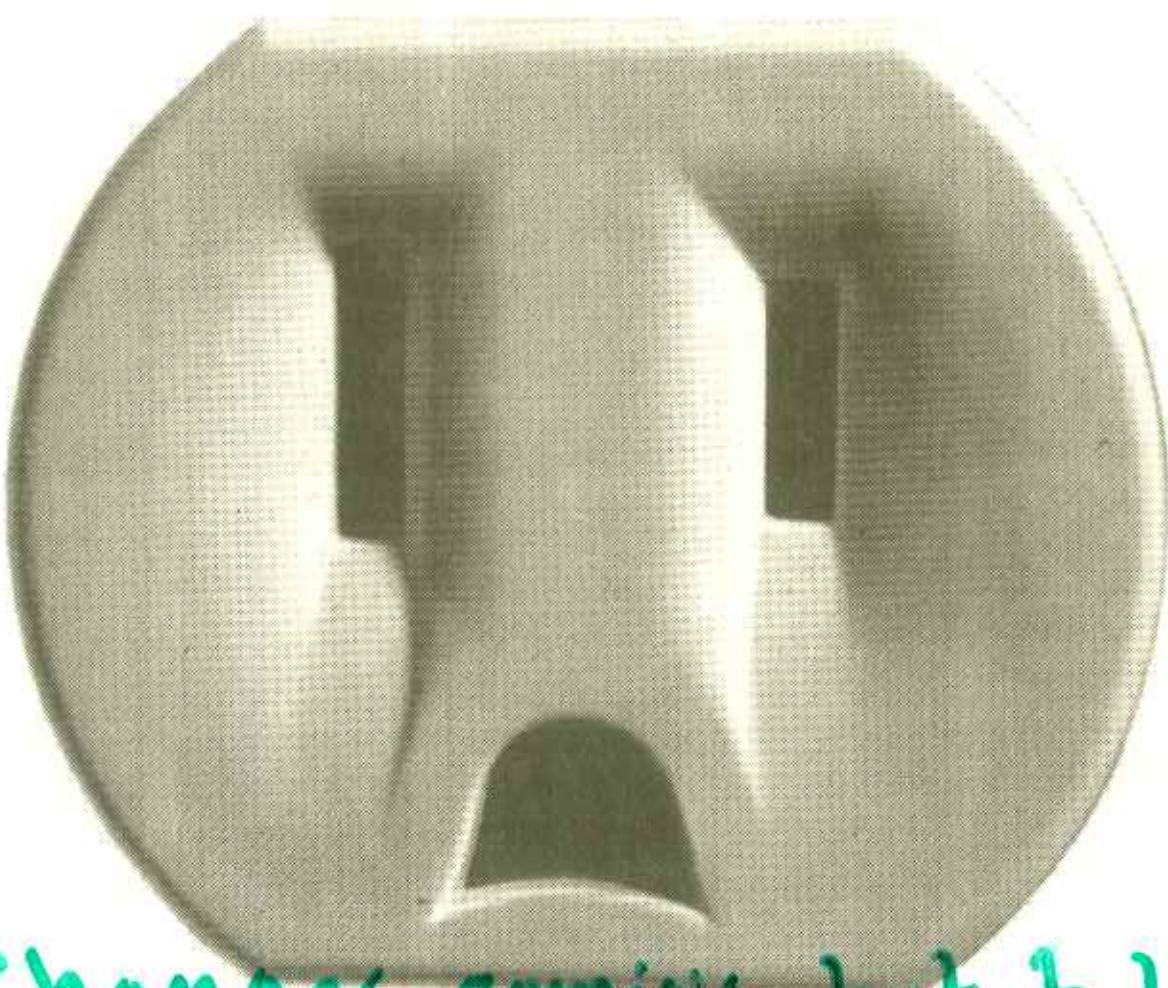


Chapter 10 #1

Transmission

- Conservation Talks Review
- Demand
- CO₂ Production
- Grid Monitor
- Transformers
 - Coil Wiring
 - Measurements
 - Parallel Transformers
- Transmission
- Grid Failures

Meet Sad Socket



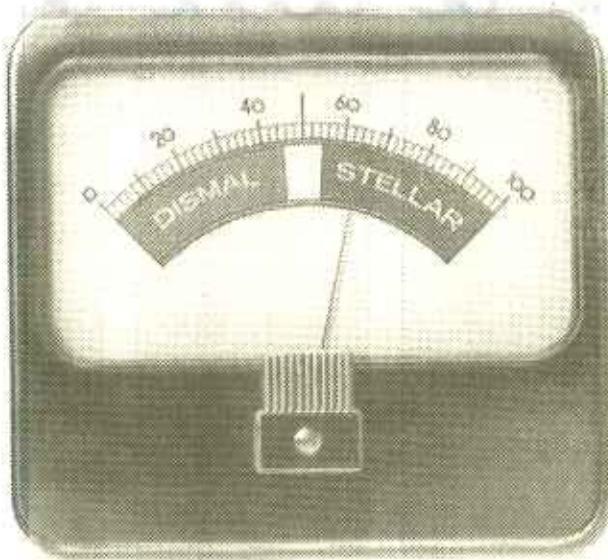
Changes coming but today
No smart P meters

No P savings "Negawatts"

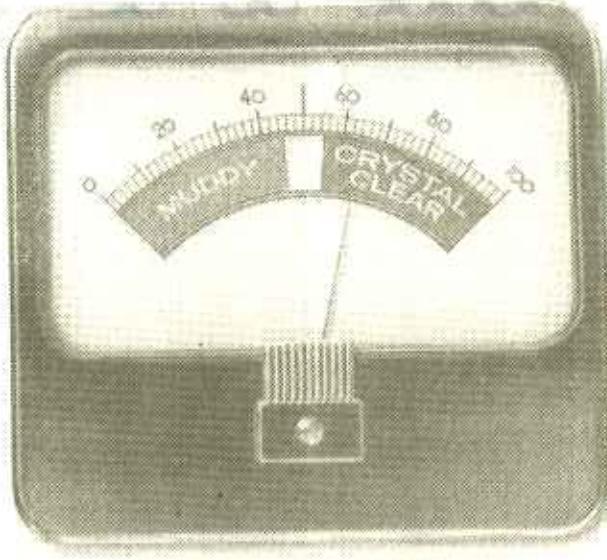
via:

- CFL & LED ↔ just starting
- Motor Control

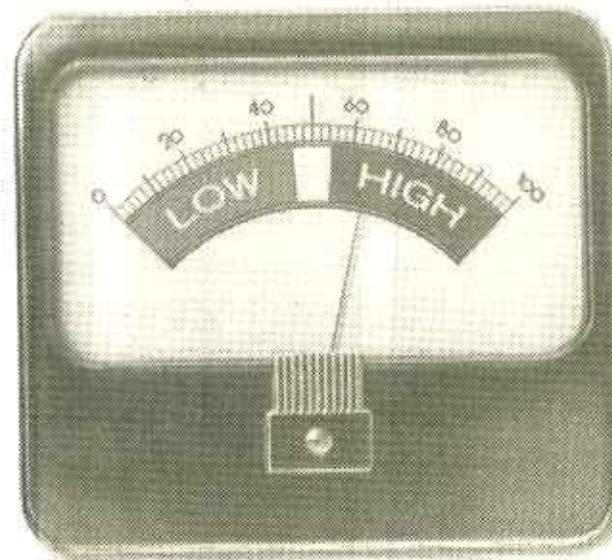
No smart grid



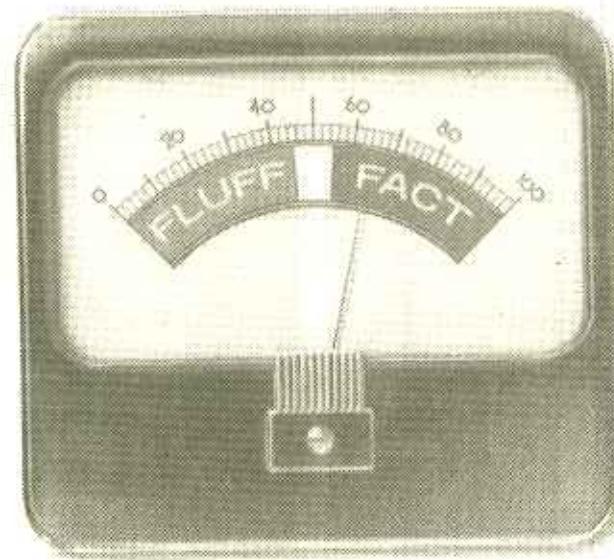
© PERFORMANCE ©



© CLARITY ©



© RISK ©



© HONESTY ©



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

$$L = 0$$

$$= \frac{x + \sqrt{5}}{2} \sim 1.618$$

$$X = \frac{1 + \sqrt{5}}{2} \sim .618$$



$$1 + \frac{1}{1 + \frac{1}{1 + \frac{1}{1 + \frac{1}{\dots}}}}$$

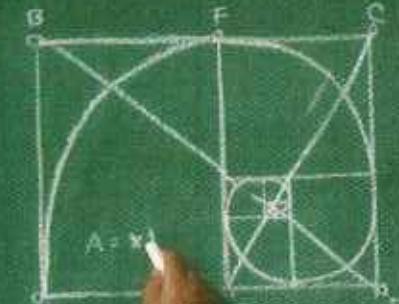
$$\frac{AD}{AB} = \frac{AE}{ED}$$

$$= X$$

$$X^2 - X - 1 = 0$$

$$\frac{A+B}{A} = 1.618$$

$$\frac{A}{B} = 1.618$$



$$FE : ED = \Phi$$





Matters of Degree

Top degrees in demand at the
bachelor's level

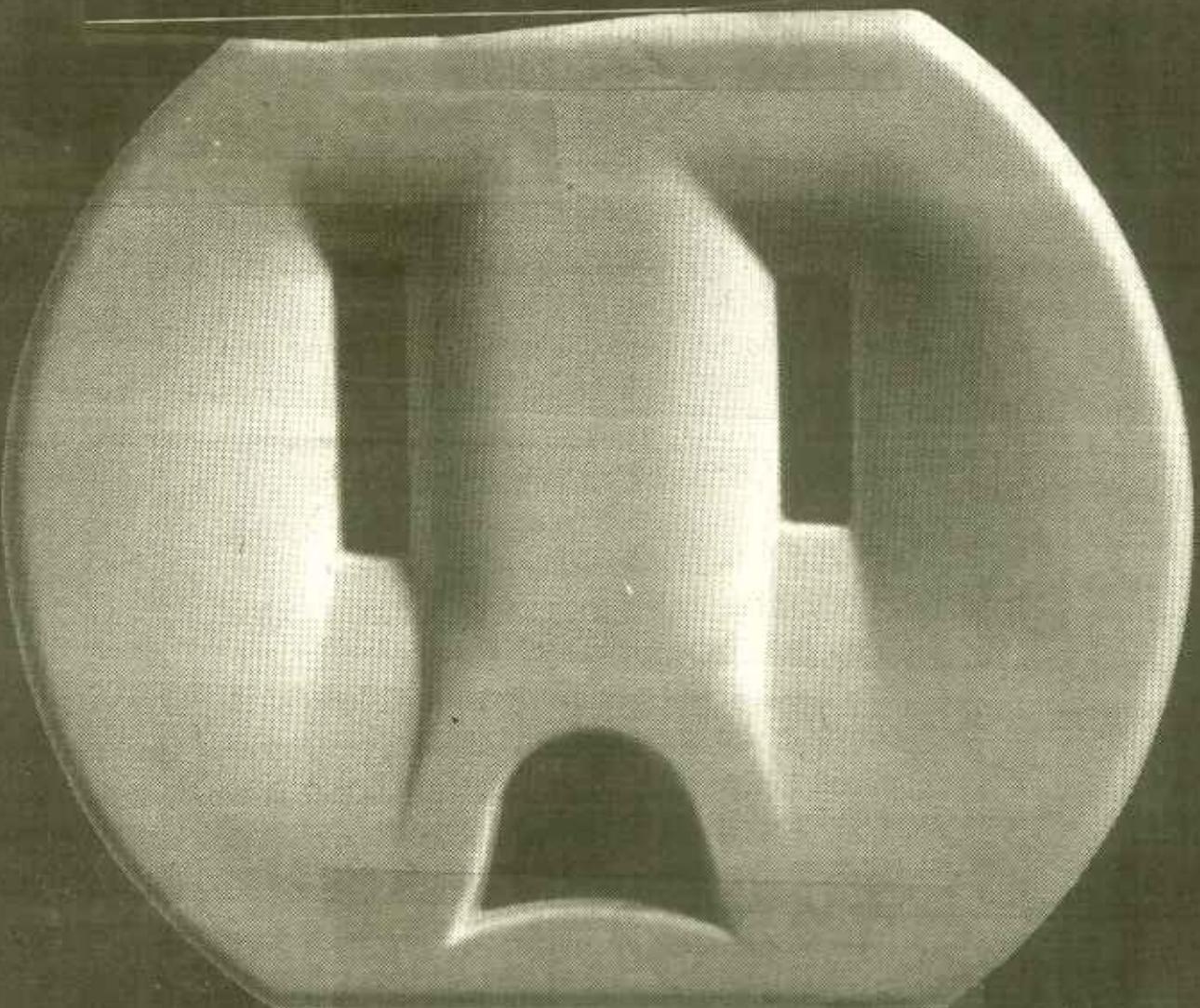
- 1. Accounting
- 2. Electrical engineering
- 3. Mechanical engineering
- 4. Business administration/management
- 5. Economics/finance
- 6. Computer science
- 7. Computer engineering
- 8. Marketing/marketing management
- 9. Chemical engineering
- 10. Information sciences and systems

3 Combo

Engr
Business

Source: National Association of Colleges and Employers,
Job Outlook 2005

Sad Socket



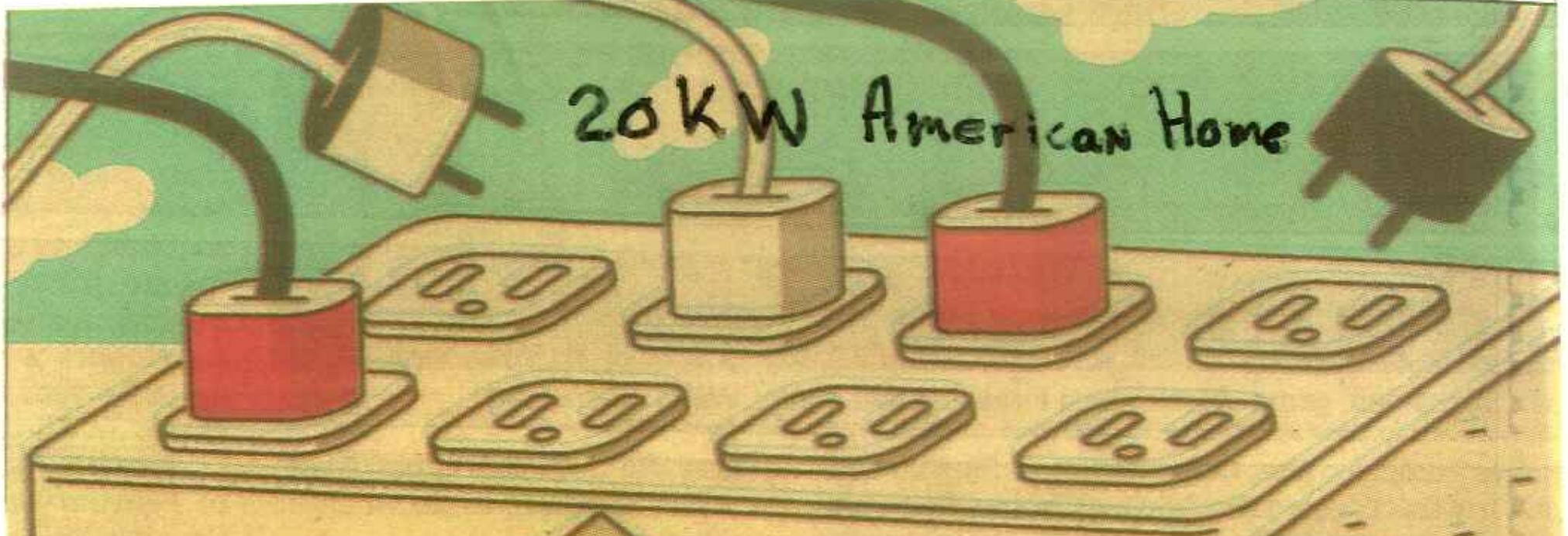
Gets Smart!

Smart
meters
grid

Higher
efficiency
components

Lower P
use by
less comfort

20kW American Home



Should we reduce to 10kW

**if you
build it,
will they
pay?**

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.

¹Energy consumption in kilowatt-hours per cycle

²Energy consumption in kWh per hour

³Energy consumption in kWh per year
Source: Association of Home Appliance Manufacturers

Up on the roof

Vegetation

Growth medium

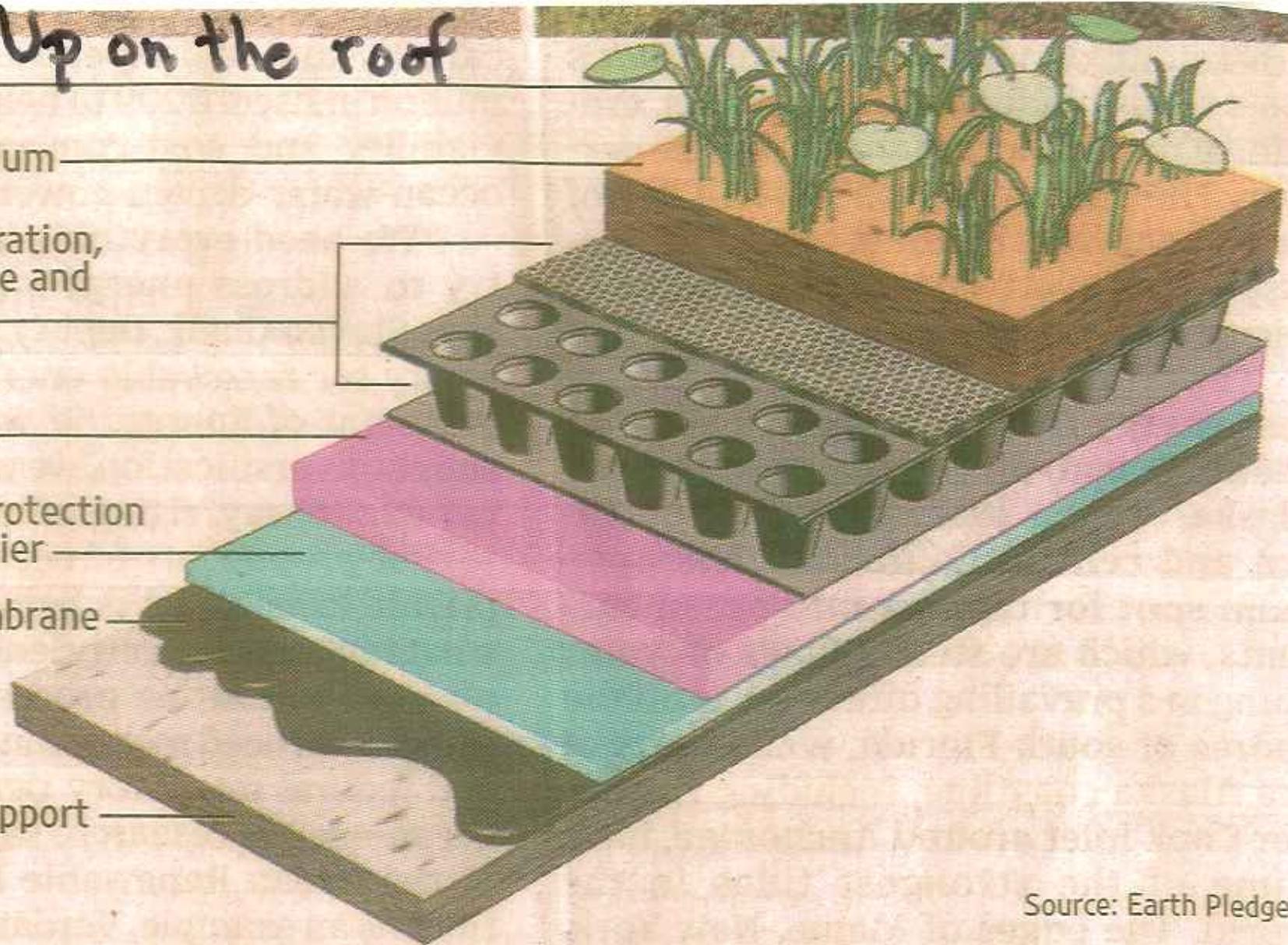
Drainage, aeration,
water storage and
root barrier

Insulation

Membrane protection
and root barrier

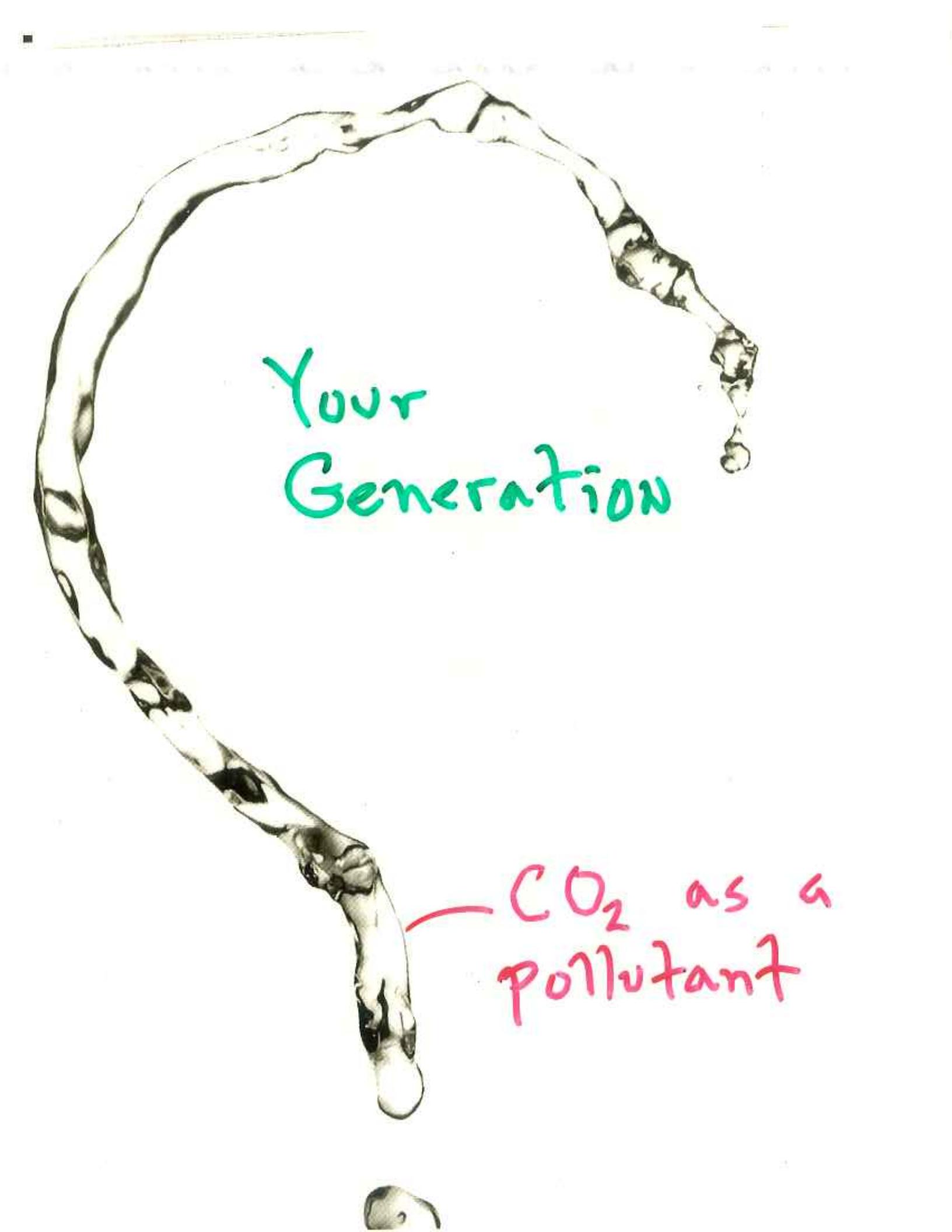
Roofing membrane

Structural support



Source: Earth Pledge

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



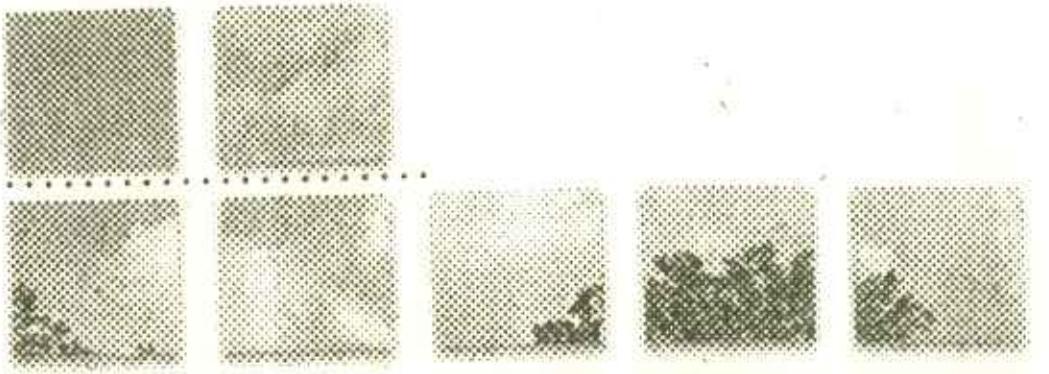
Your
Generation

CO_2 as a
pollutant

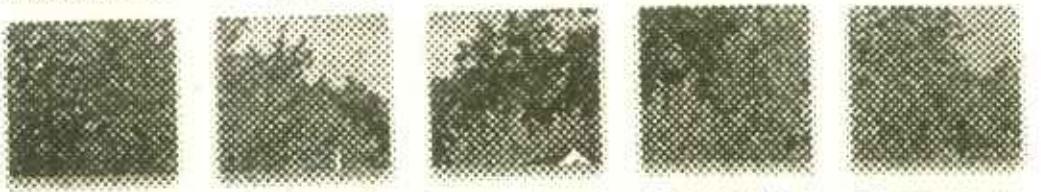
Sources of emissions under consumers' direct control

37%

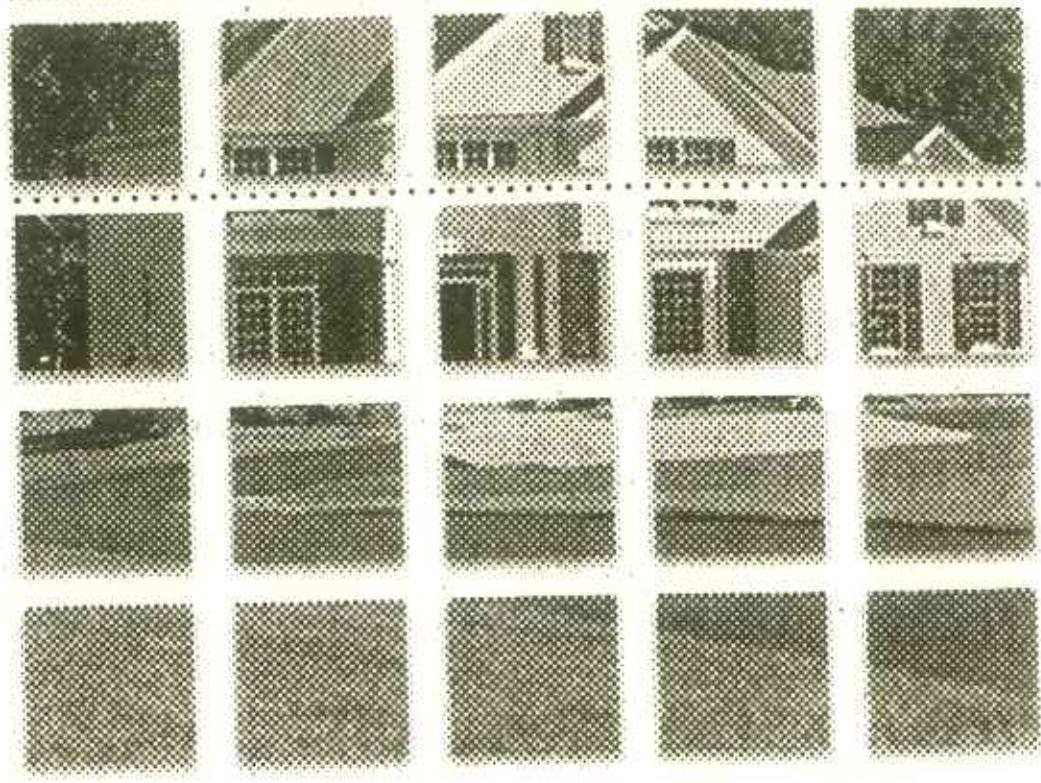
Passenger air travel, **2%**

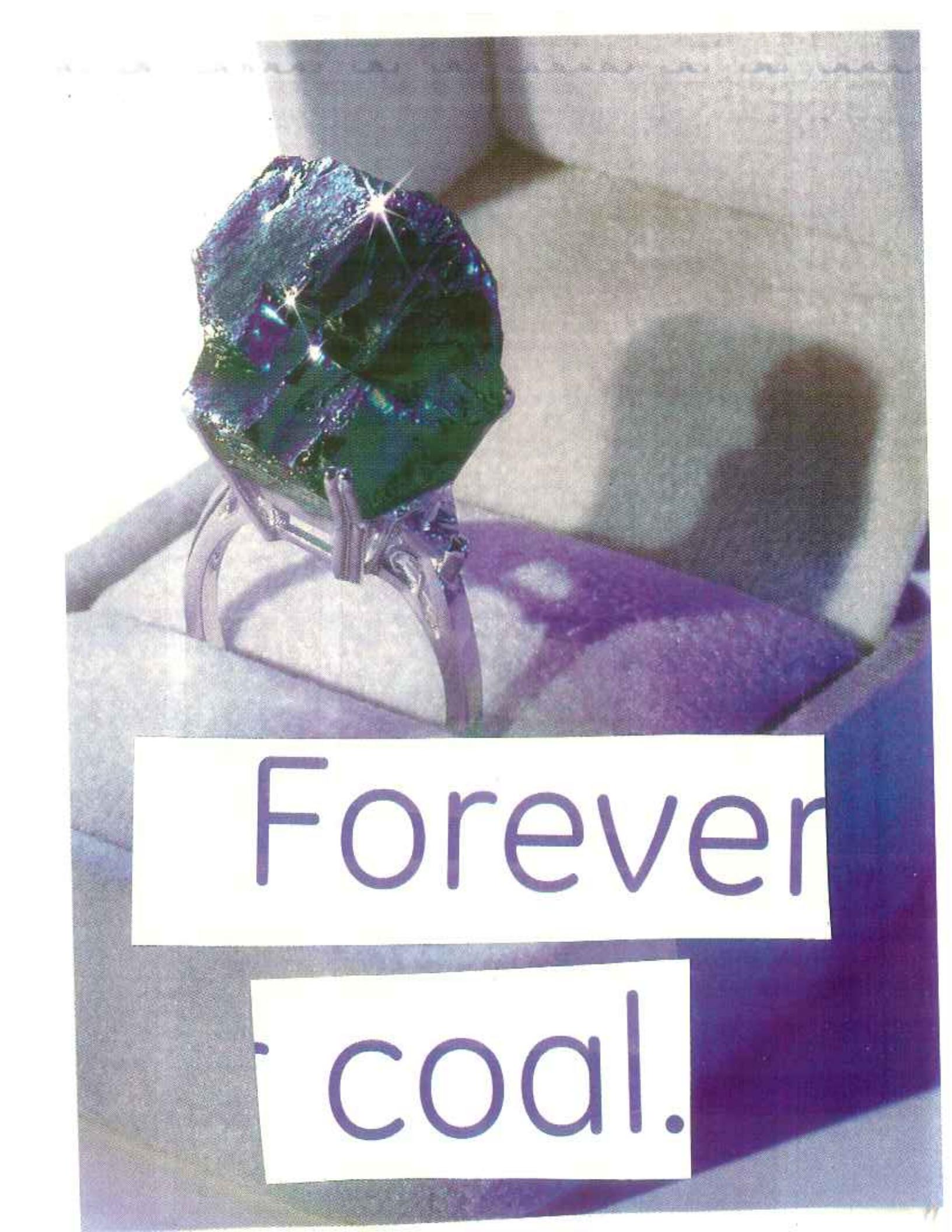


Passenger cars
17%



Residential buildings and appliances*
17%





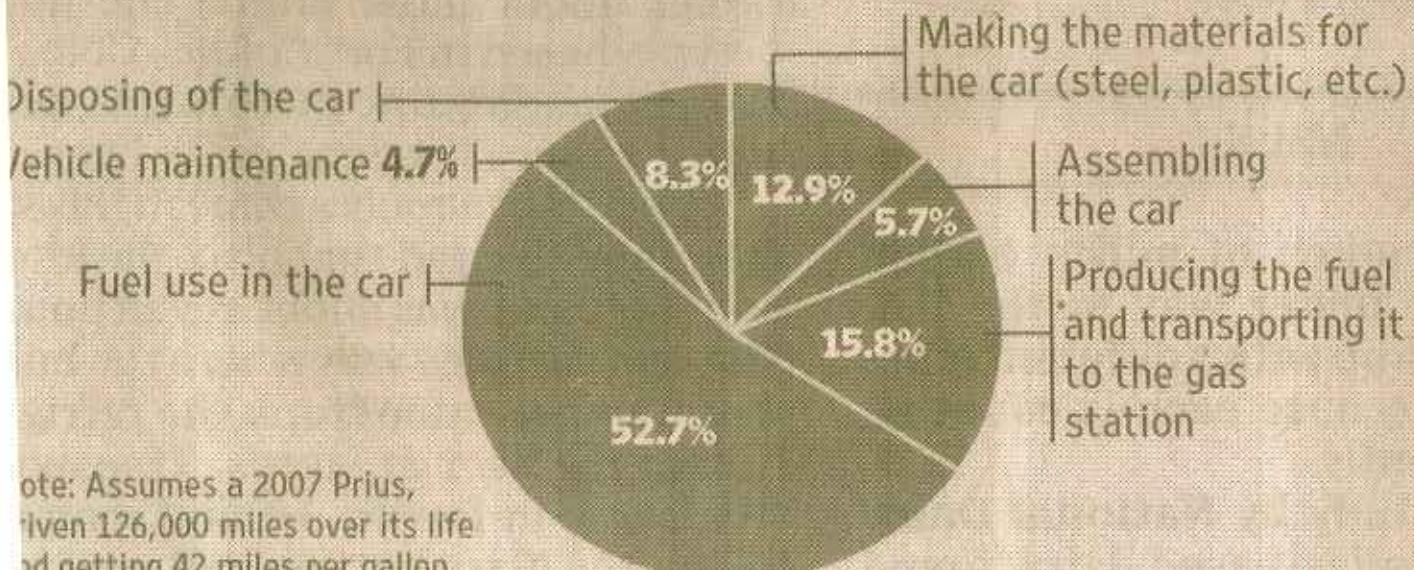
Forever
coal.

Carbon Footprints



CAR Toyota Prius

TOTAL FOOTPRINT: 97,000 pounds



Carbon Use

BOOT

121 Pounds

PAIR OF HIKING BOOTS Timberland Winter Park Slip On Boots

TOTAL FOOTPRINT: 121 pounds

Producing the
raw materials

Electricity used
in shoe assembly

7%

93%

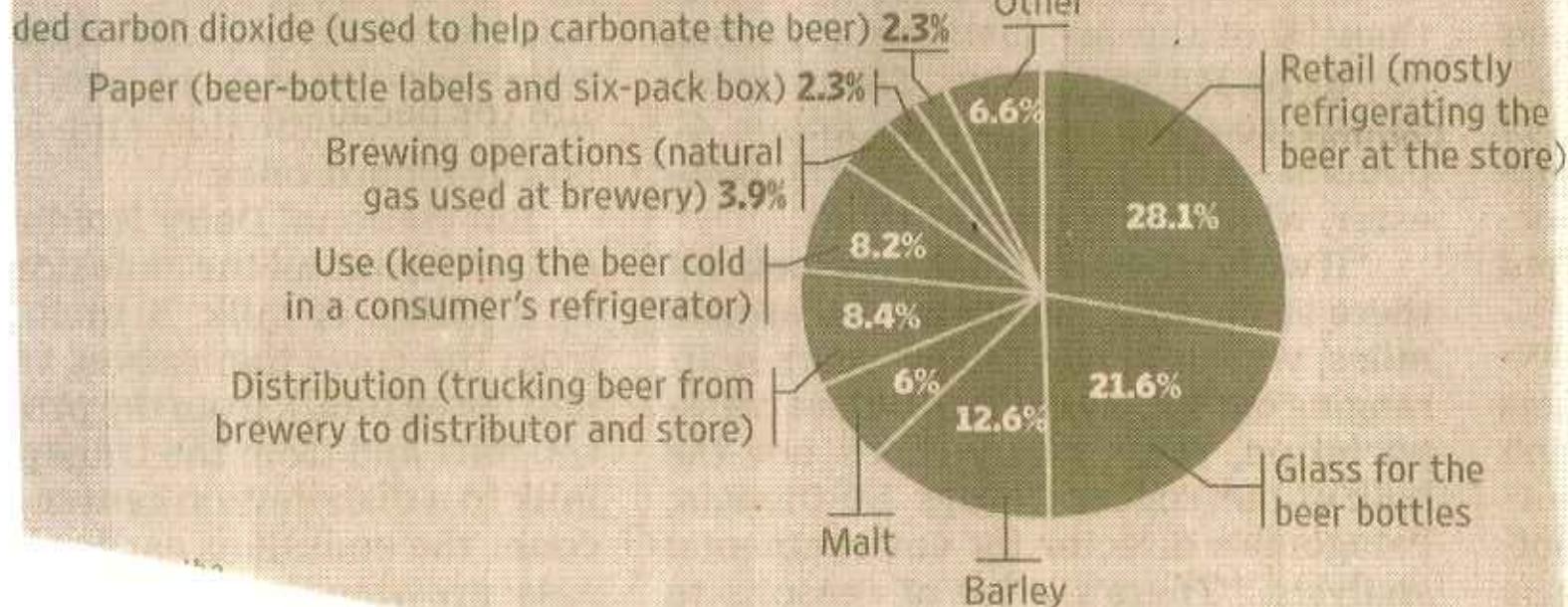


BEER

7 Pounds

SIX-PACK OF BEER | Fat Tire Amber Ale

TOTAL FOOTPRINT: 7 pounds



Carbon Generation

FLEECE JACKET



66 Pounds

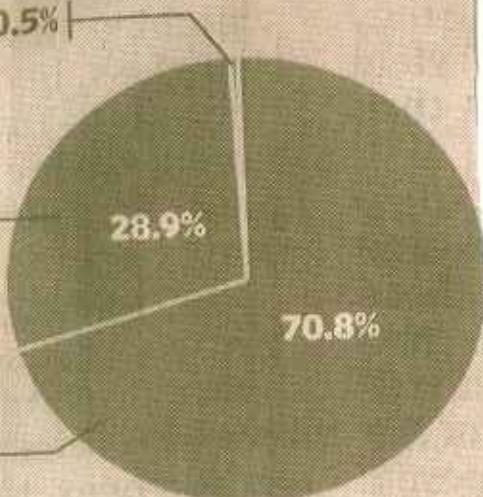
FLEECE JACKET Patagonia Talus jacket

TOTAL FOOTPRINT: 66 pounds¹

Design and marketing 0.5%

Making the fabric and
assembling the jacket

Producing
the polyester



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

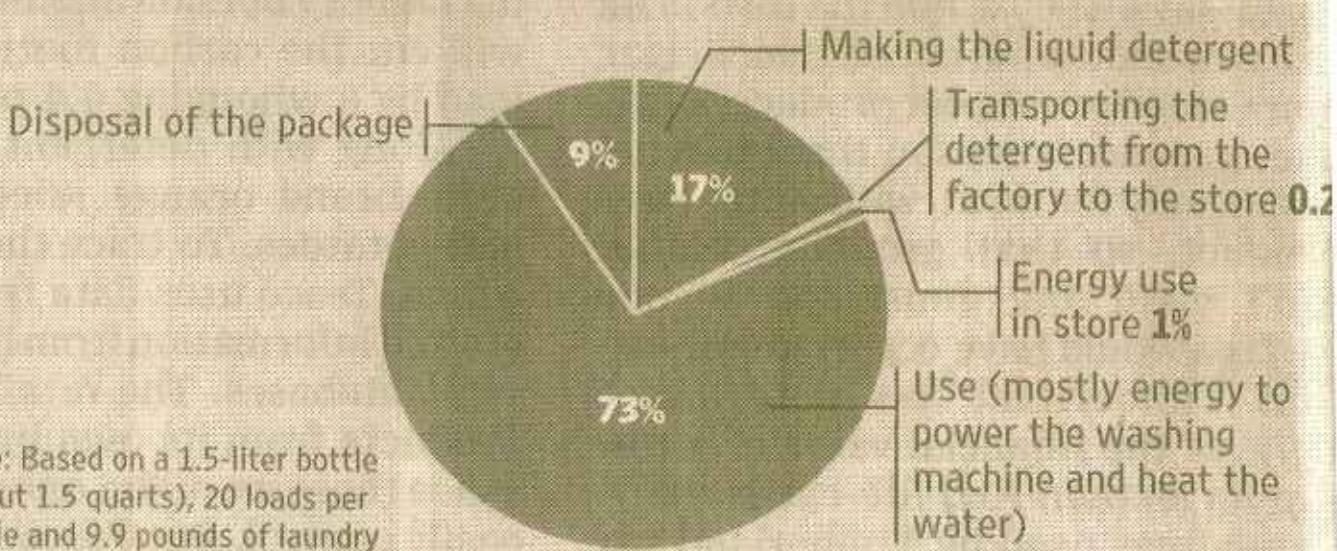
LAUNDRY DETERGENT



31 Pounds

LAUNDRY DETERGENT Tesco Non-Biological Liquid Wash

TOTAL FOOTPRINT: 31 pounds



MILK



HALF-GALLON OF MILK Aurora Organic Dairy

TOTAL FOOTPRINT: 7.2 pounds²

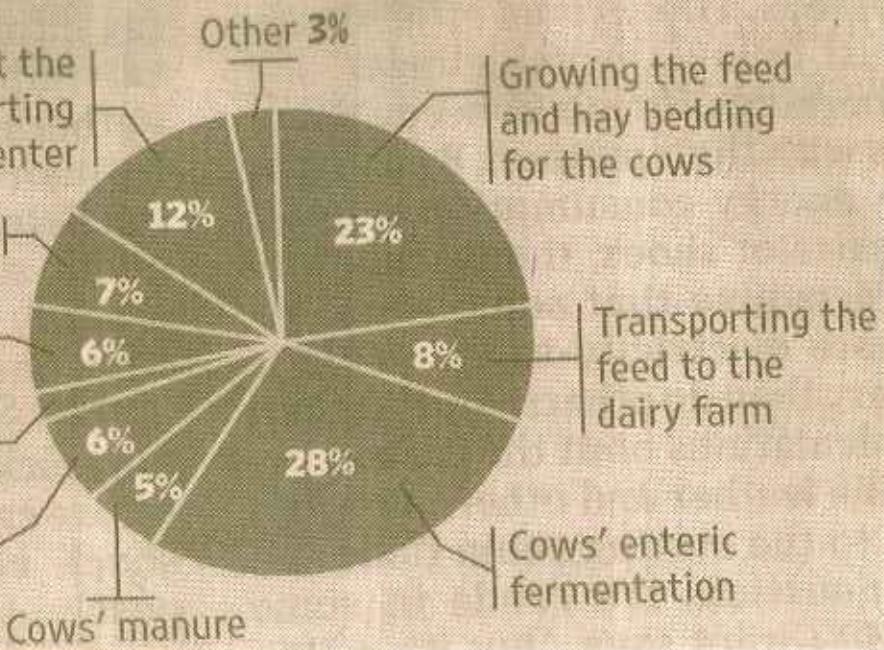
Storing the packaged milk at the processing plant and transporting it to a distribution center

Packaging for the milk

Fuel and electricity use at the processing plant

Transporting the raw milk to the processing plant 2%

Fuel and electricity use on dairy farm



ELECTRIC ENERGY

A PUBLICATION OF **RMEL**

Issue 1 | 2008

Smart Grid – From Concept to Reality

Solutions for a Carbon
Constrained World

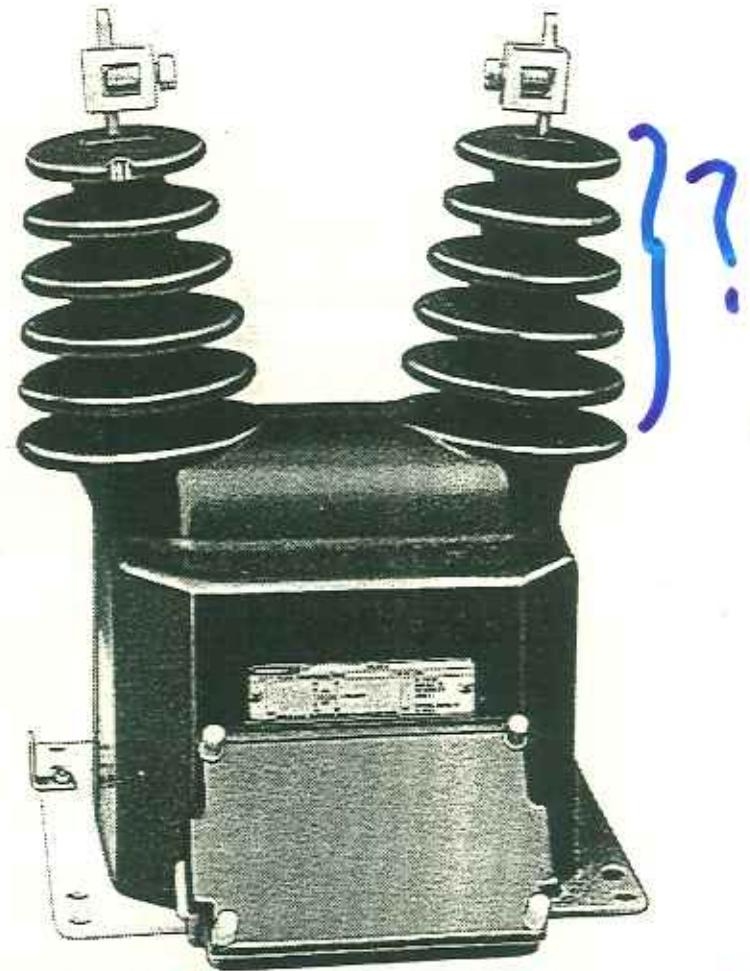
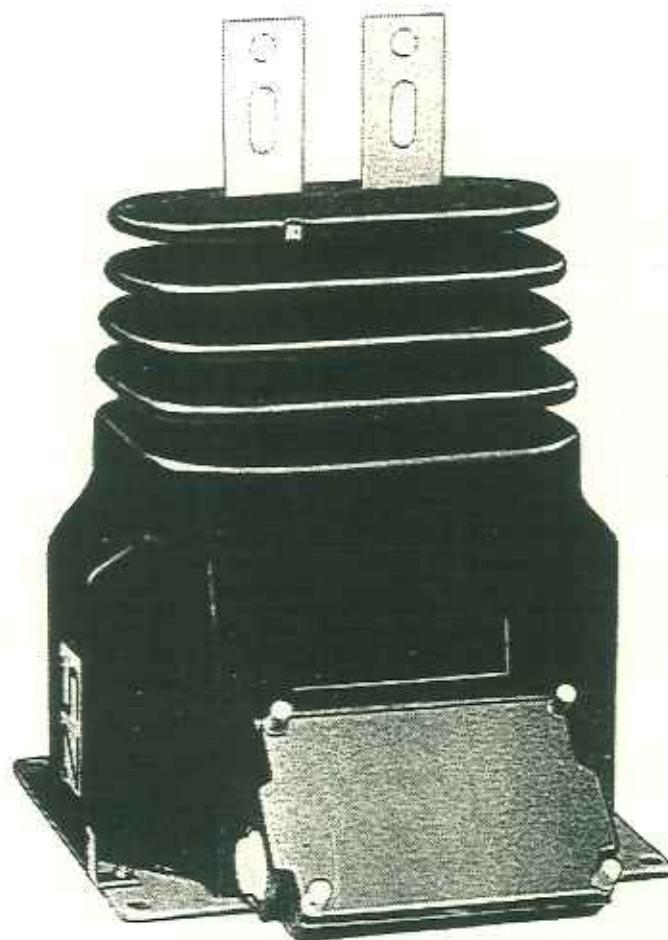
Developing a Clean and Diverse
Energy Portfolio for the West

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_{le}, I_{le}

Instrument Transformers

Why stray C a worry?

Instrument / Measuring Trfs

3

Voltage Trf



any i? $\frac{V_{IN}}{V_{out}}$ any HV

V_{out}

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

std in
POWER
INDUSTRY

115 V full scale

69 kV line

Fig 11.11

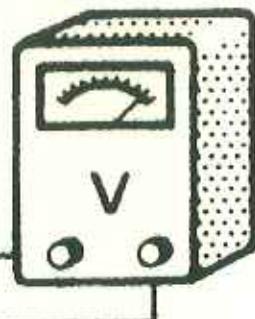
pg 230

primary
insulation

distributed
capacitance

secondary
grounded

stand-off
HV safety
requires secondary
ground



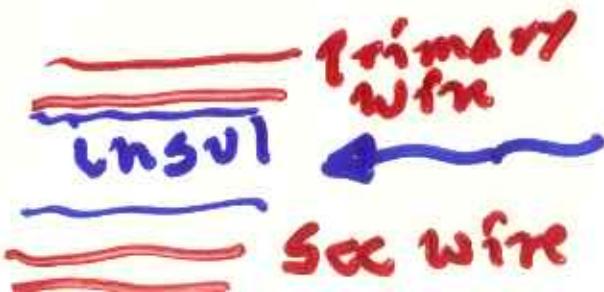
voltmeter
0 to 150 V

limited to 115 V
via ground

$$14.4 \text{ kV} \leq 115 \quad \left. \begin{array}{l} \text{full} \\ \text{scale} \end{array} \right\}$$

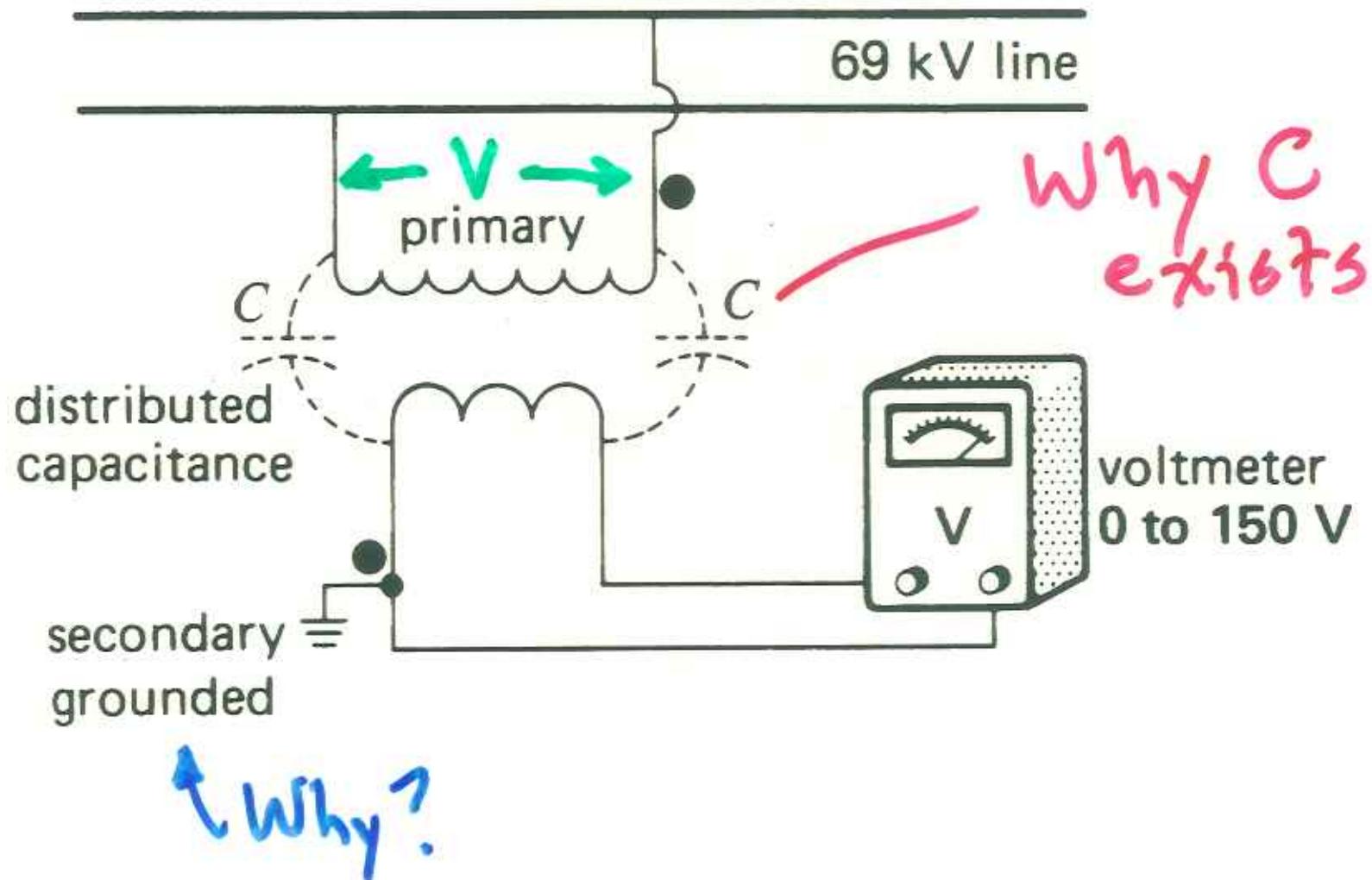
$$69 \text{ kV} \leq 115$$

To avoid
shock by ..
"parasitic"
 C

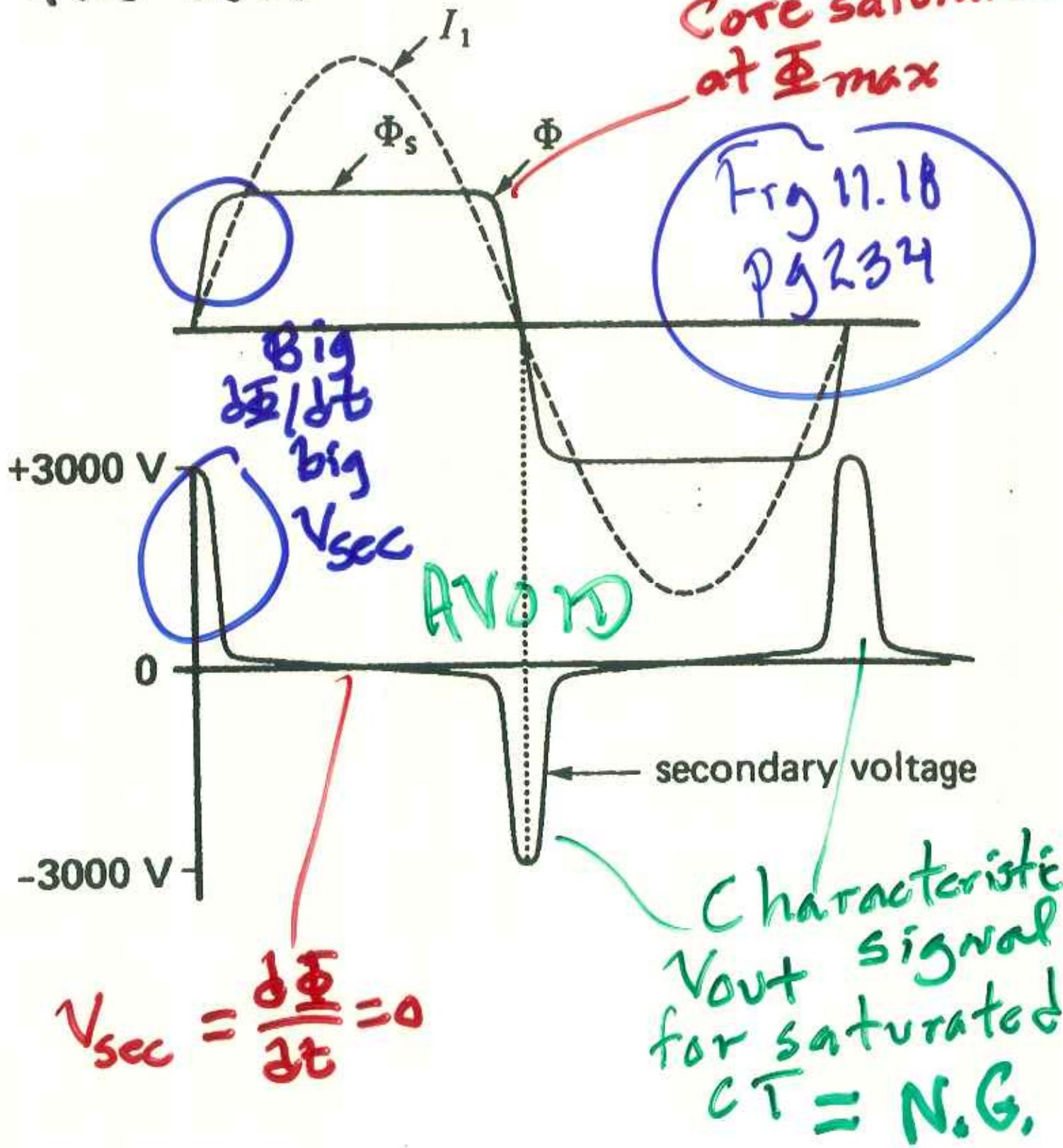


most of trf is
insulation

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

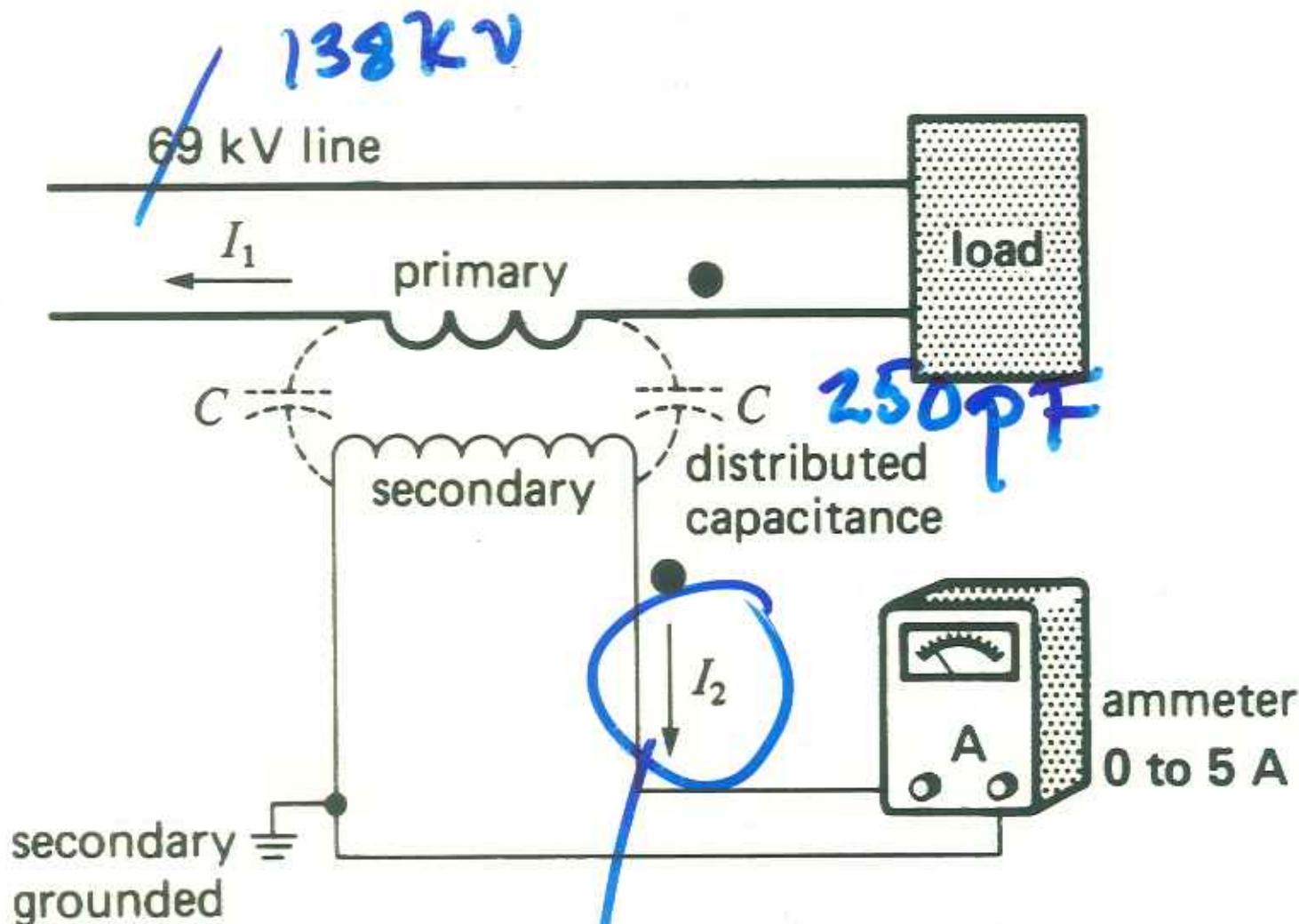


(B) CT with Z_L large (should be $\gg 0$)
 Open circuit secondary on CT is
dangerous. It also distorts
 the $i(t)$ waveform



Interf issues

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

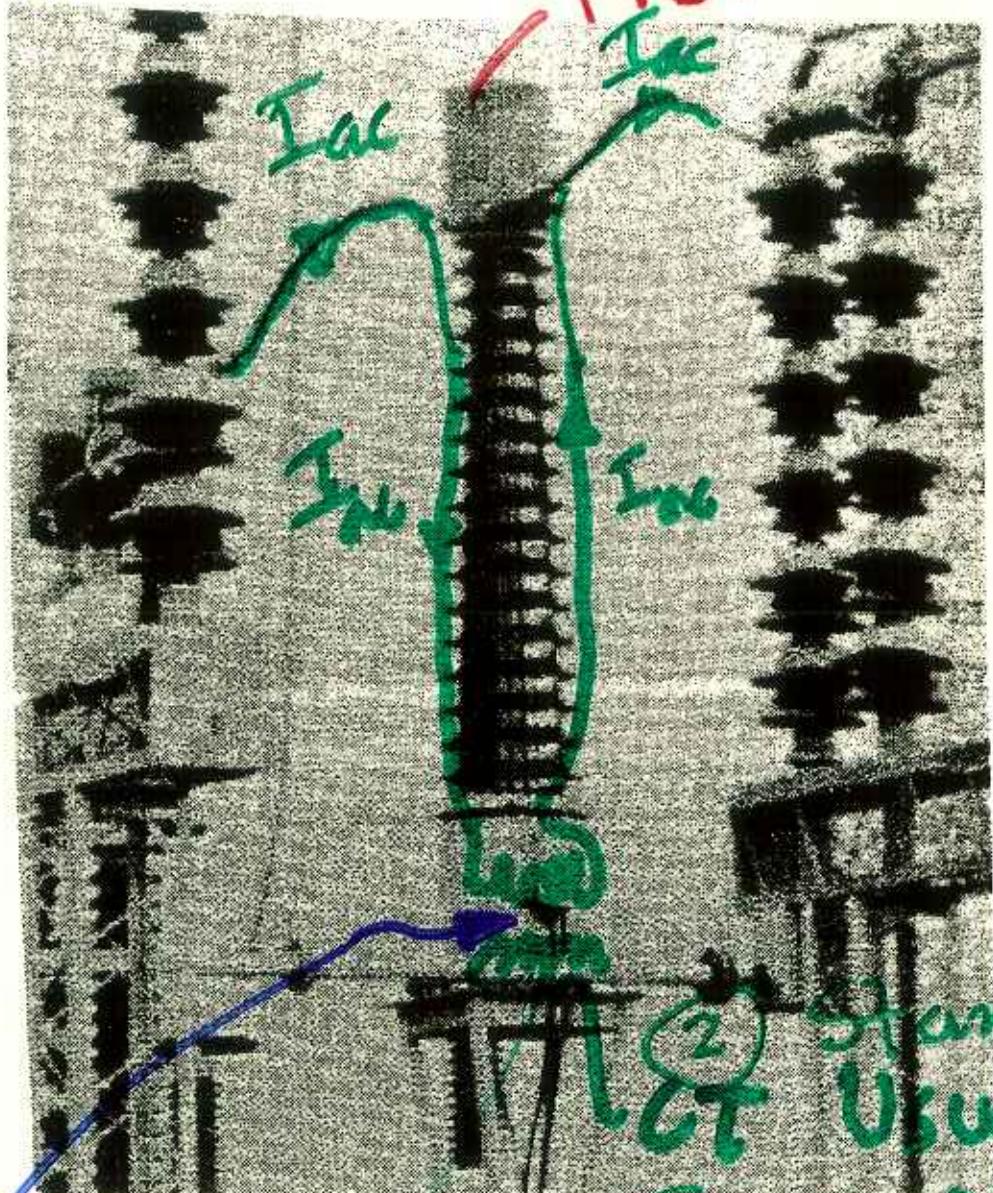


How Calculate I_{stray} ?

Current Trt (for iron HV line)

Fig 11.1b
Pg 233

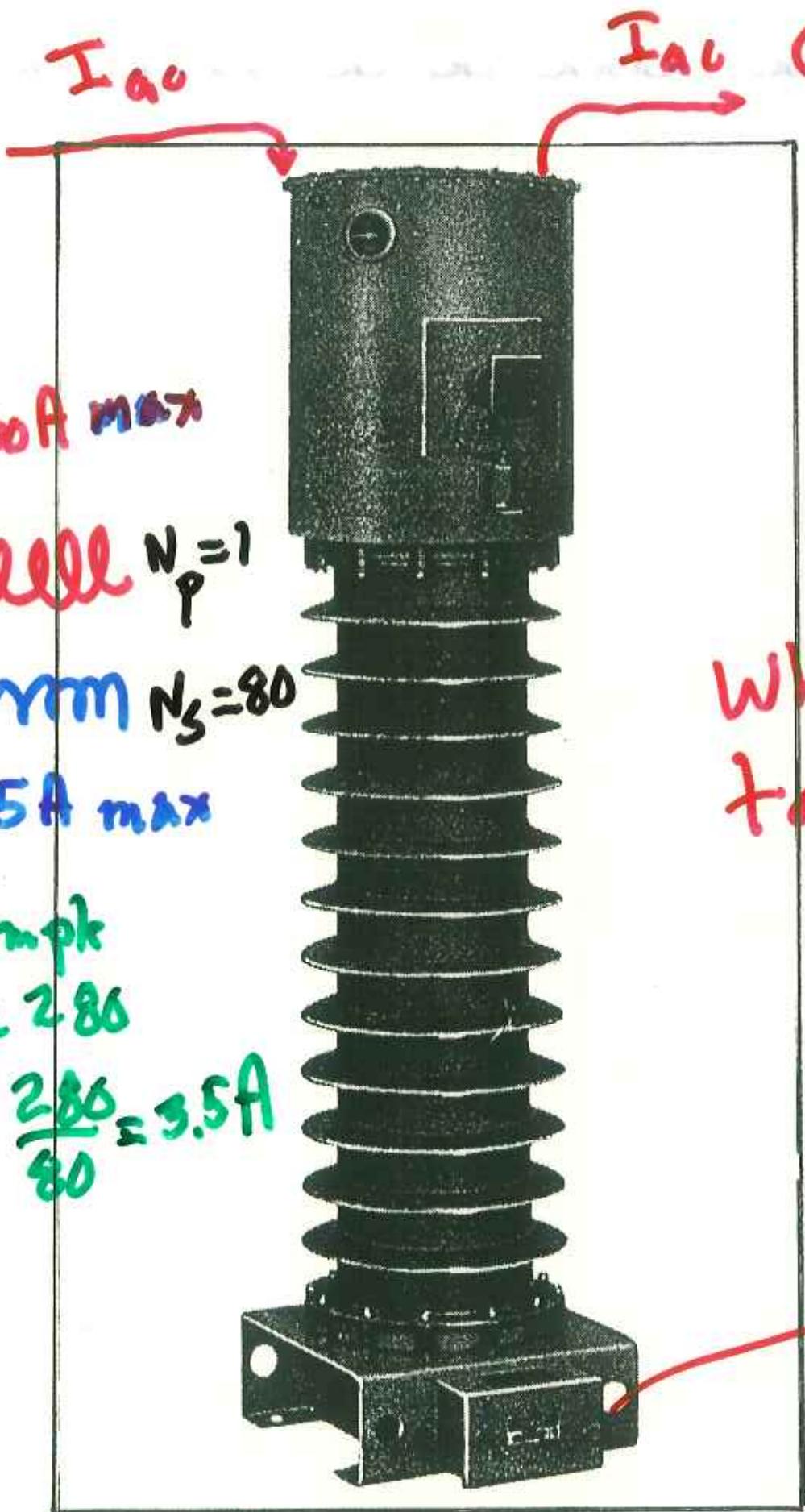
① crackly } want
220 KV AC } to
MoV } safely
measure



Mostly
Insulation

② Standard
Usually
 $I_{out} = 0-5A$
full
scale

$$\textcircled{3} \quad S_{CT} = I_p V_p = I_s V_s$$



I_{ac} @ 250 kV
 1MV
 Whoa!

Why so tall?

I_{out}
 0-5A
 full scale

Is there other ways to
 insulate / isolate

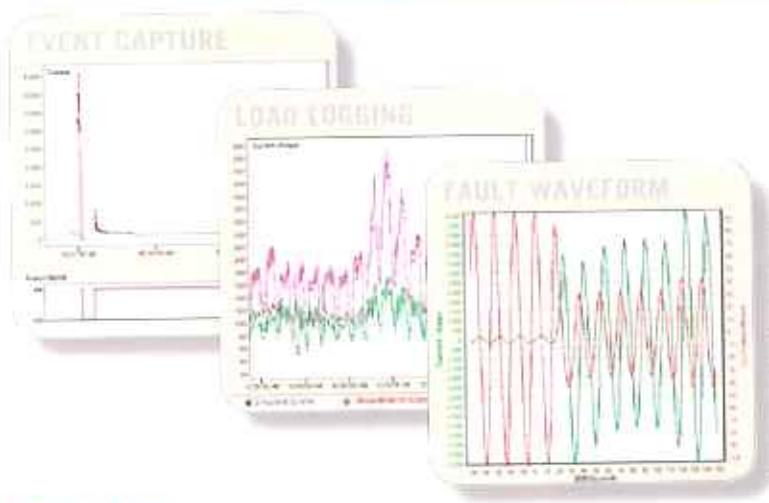
LineTracker

Intelligent Grid Monitoring

Distribution Load Logger
& Fault Recorder

- 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

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

LT40 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.



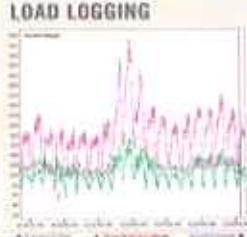
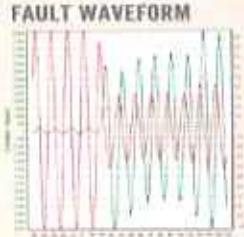
Remote Monitoring

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

LineView 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 Low powered, license free range 150ft (46m) Cell (GSM/CDMA), TCP/IP, Lanwire, Satellite SCADA & Historian integration tools available
Energy Storage	1x2V 8Ah rechargeable sealed lead acid battery
Power Source	0.5W solar cell
Operating Temperature	-14F (-26C) to +120F (+50C)
Survival Temperature	-58F (-50C) to +185F (+85C)
Housing Material	UV Stabilized Polycarbonate and Aluminum Diecast
Ingress Protection	IP65 Weatherproof
Dimensions	14 H x 5 L x 5 W in. (35.5 x 13 L x 13.1 cm)

Measured Parameters Fault / Event Capture

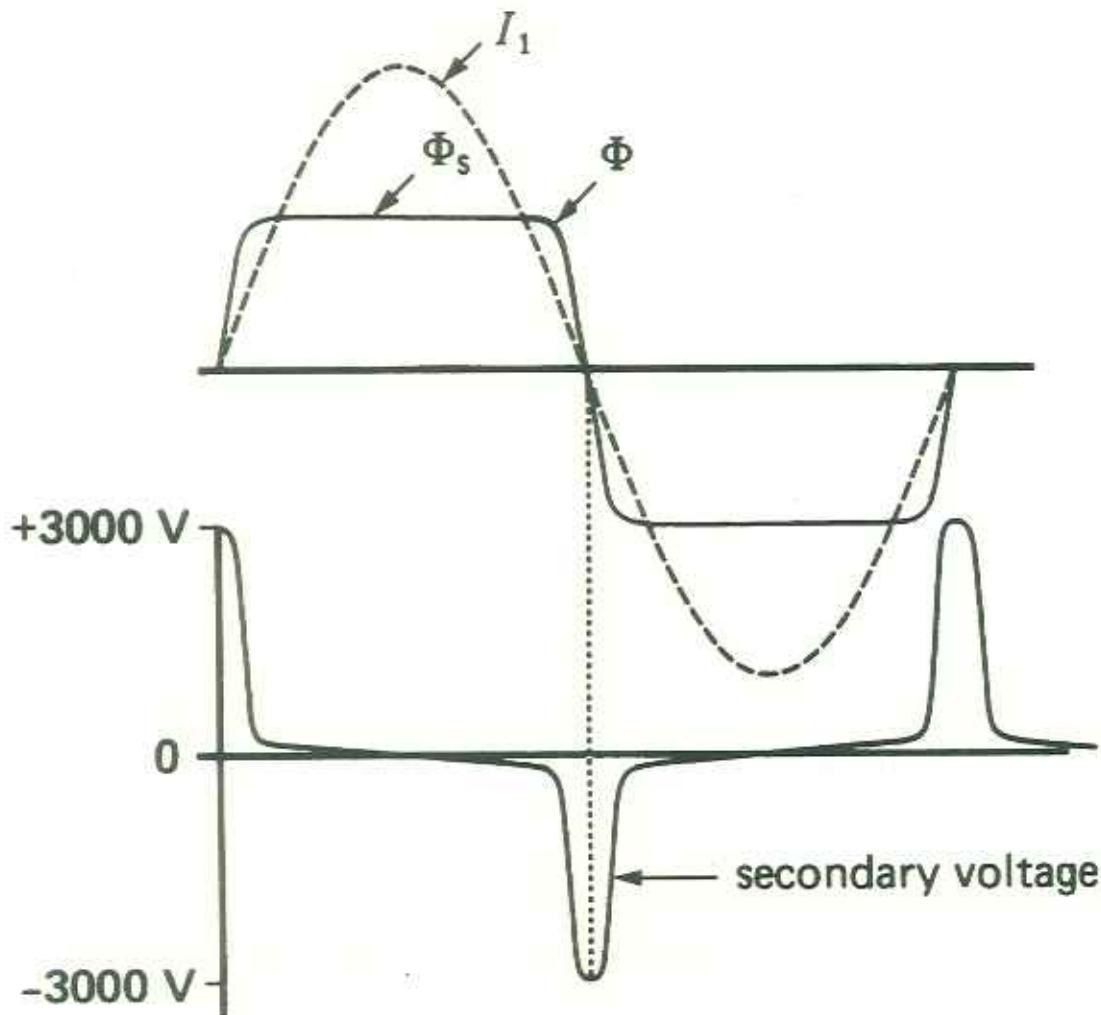
Protection Operations	
Power Outage	
Power Restoration	
Load Profiling	
Sample Rate	
Accuracy	
Memory Storage Capacity	
RMS Records (60sec)	
Fault Waveforms	
Load Profiling	
Weight	

Current and Power (On/Off)	
<0.5 Sec RMS profile (I & E-Field)	
Pre-event Line Loading	
Fault Current Magnitude up to 25kA	
Fault Current Waveform (12-cycles)	
E-Field Waveform % Change (12-cycles)	
Post-event Line Loading	
Time to Trip	
Number of Trips	
Flash Current	
Time of Power Off	
Time of Power On and Outage Period	
Three defined averaged profile (1-60 mins)	
Current 1200Hz, E-Field 600Hz	
Current +/- 5% of reading +/- 2A	
Rolling partitioned memory	
100+ events	
34	
Up to 80 days	
4.4 lbs (2kg)	

Open Circuit CT

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

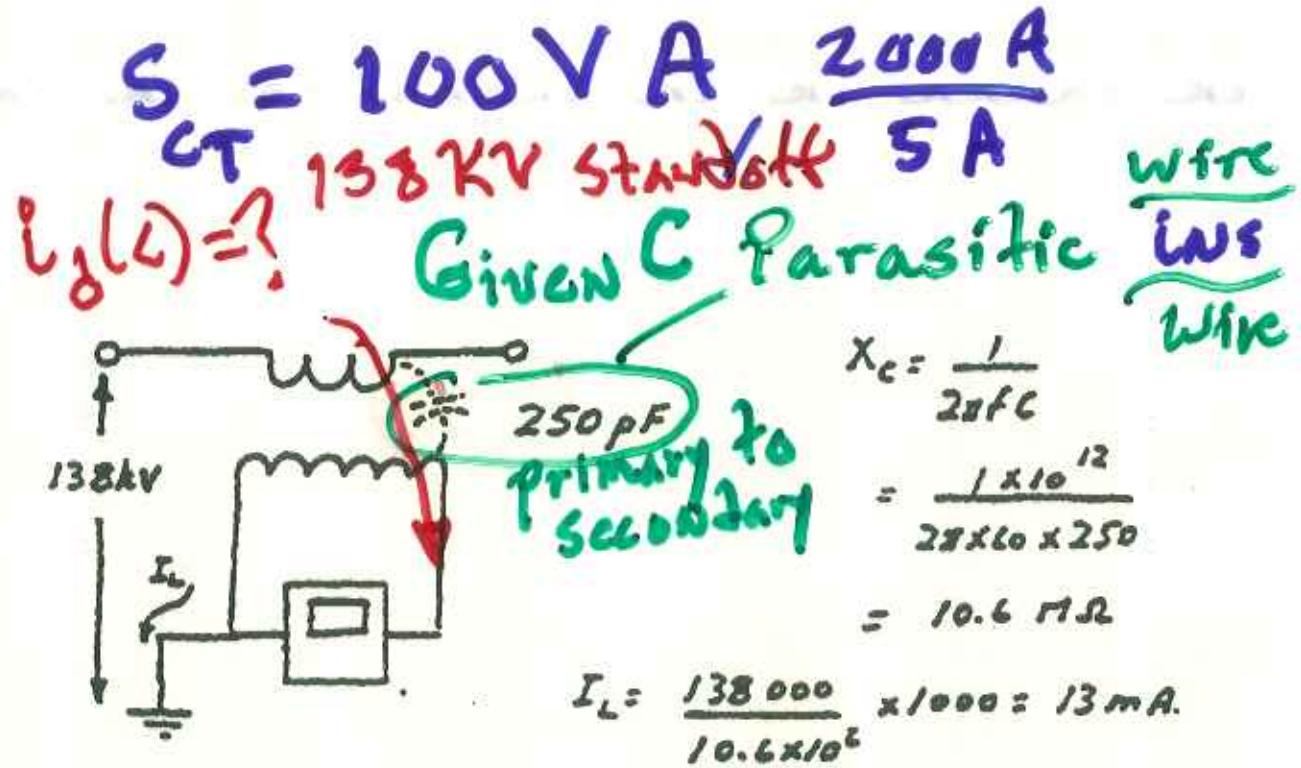
Creates Undesired saturation



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

11-10

15



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

i_R (through insulation) ≈ 0

BUT

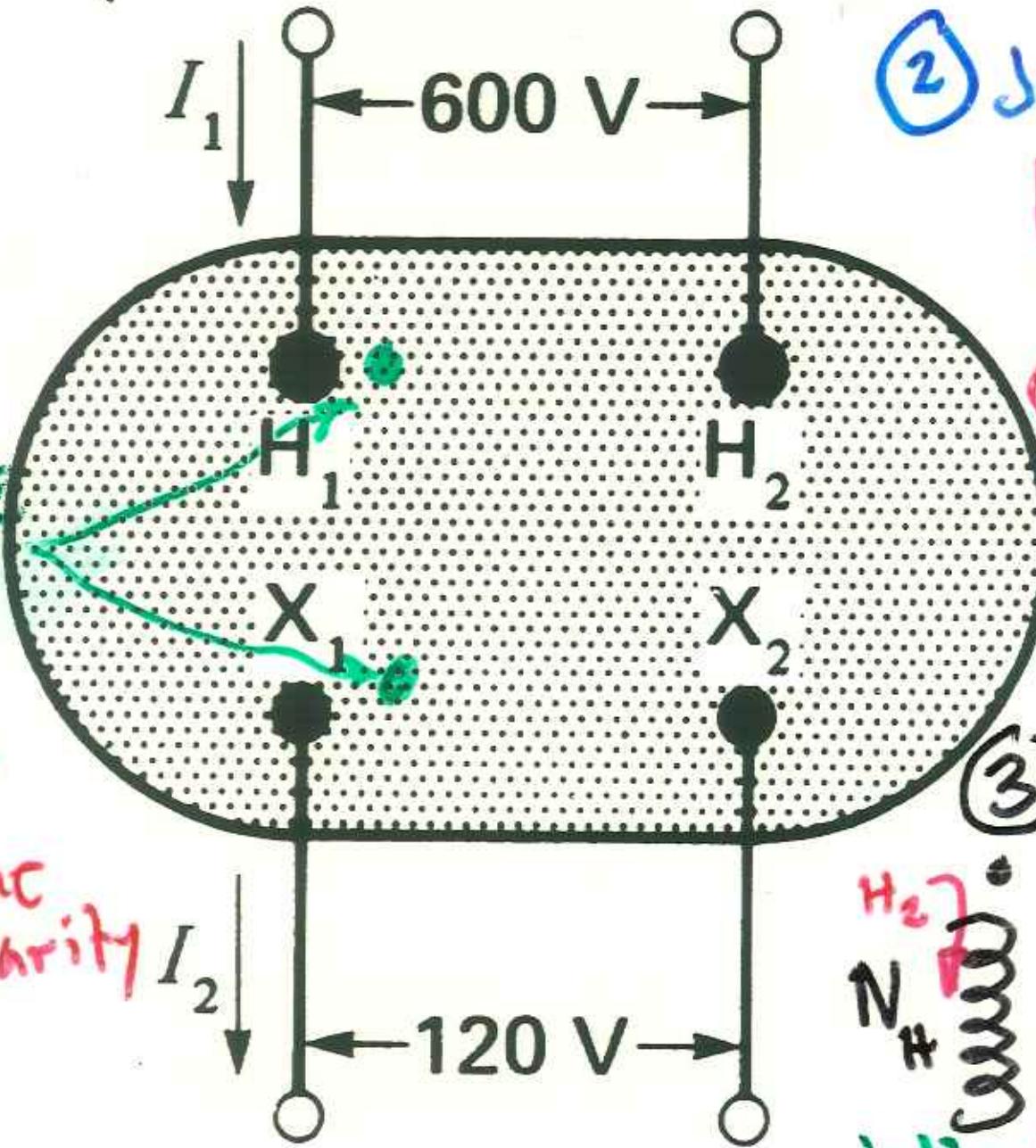
i_C (displacement current) is large!

Deadly!

Always ground CT!

Simple Transformer Review

① Dots
IEEE Std
X₁ SAME H₁
H₂ J.P.
polarity



④ $V_{H1} - V_{X2} = ?$

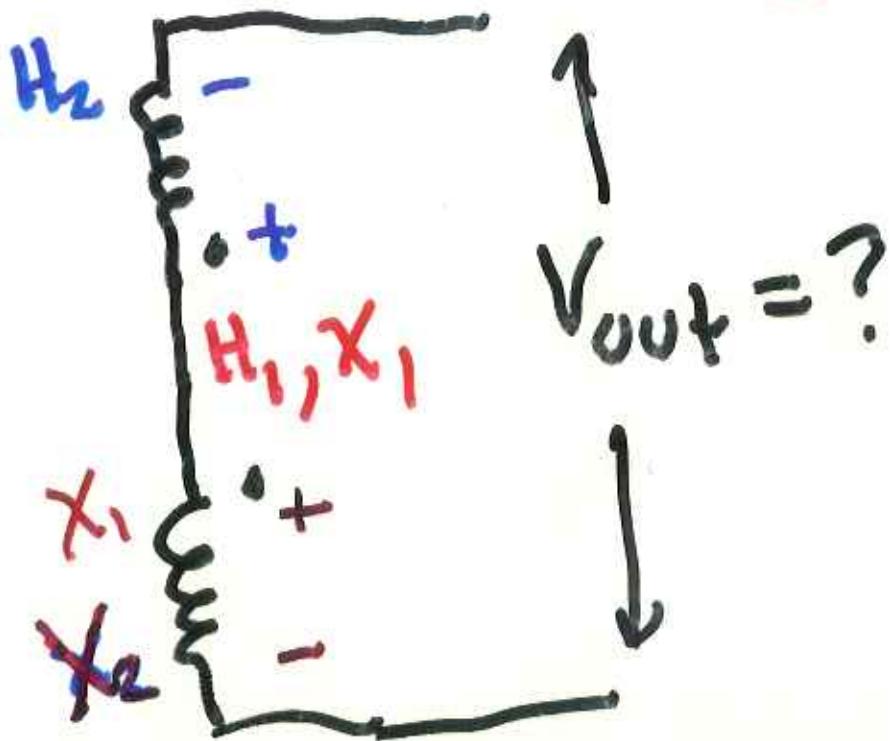
What about i flows in coils?

② Just wiring
or Other clever possibilities
600 → 120
120 → 600

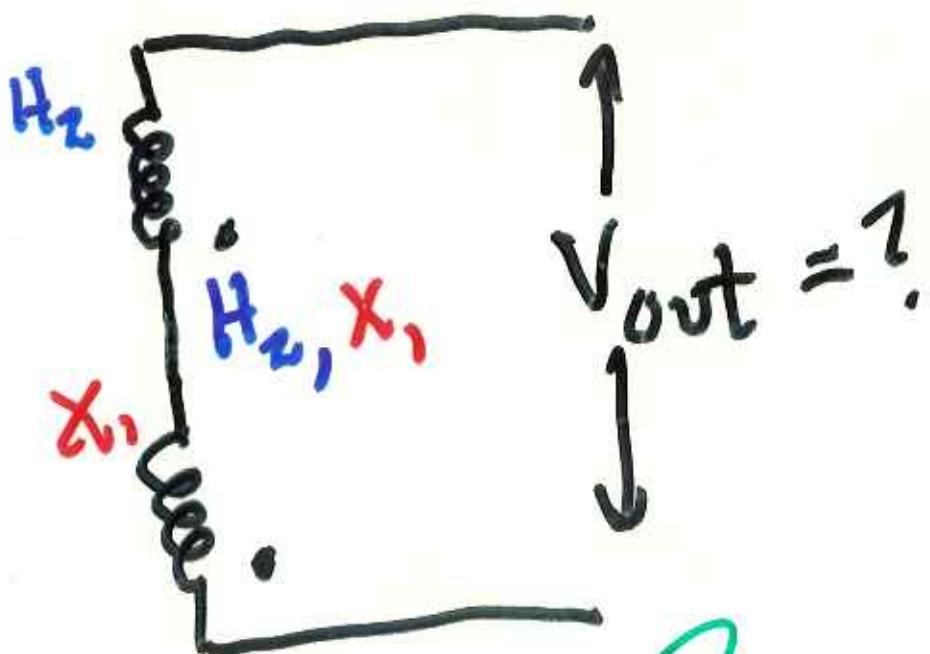
③ iflow vs Dots

$$N_H \neq N_X$$

Other Wirings



$$V(H_1 - X_2) = ?$$



Input choices?

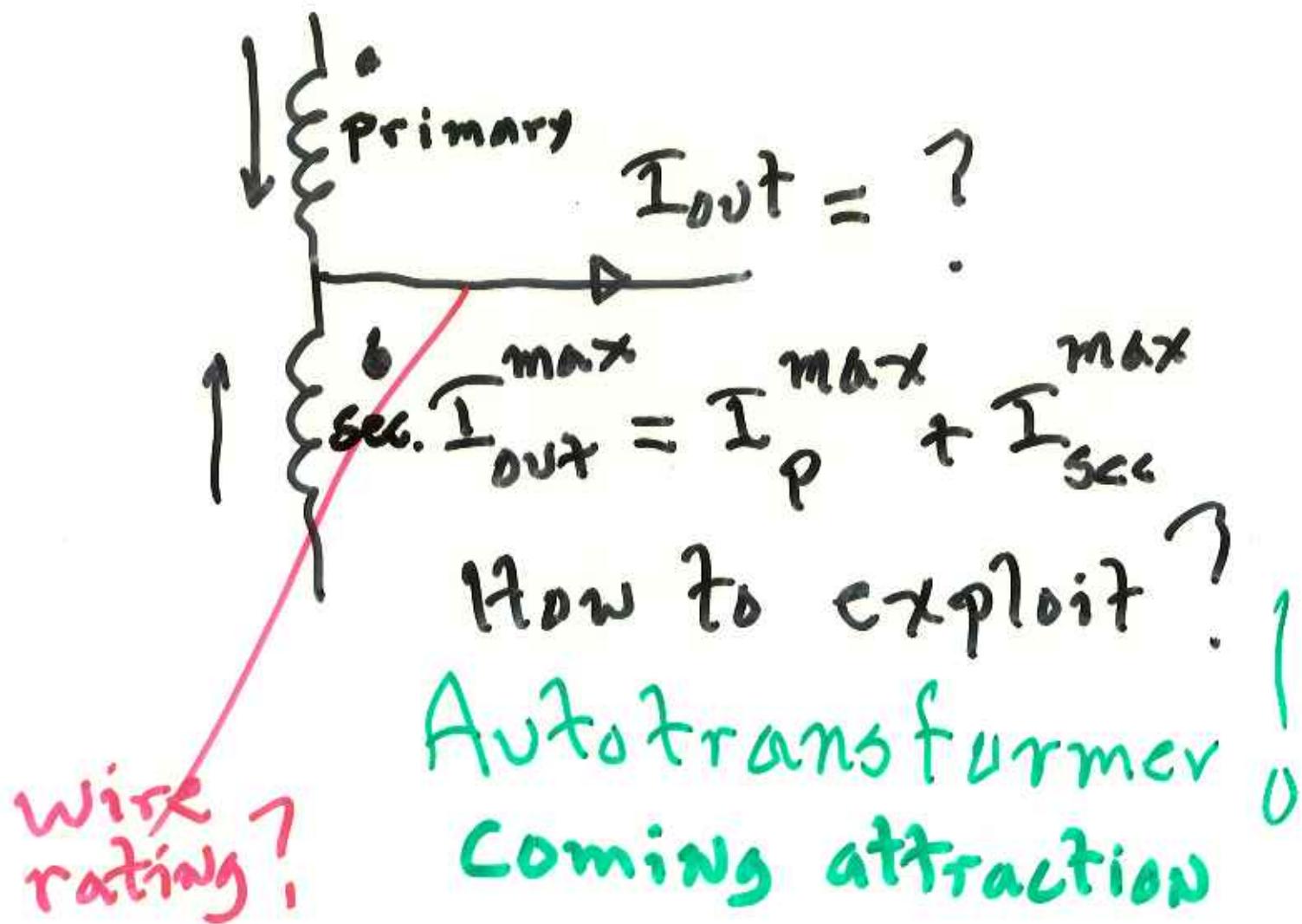
V_{IN}
120

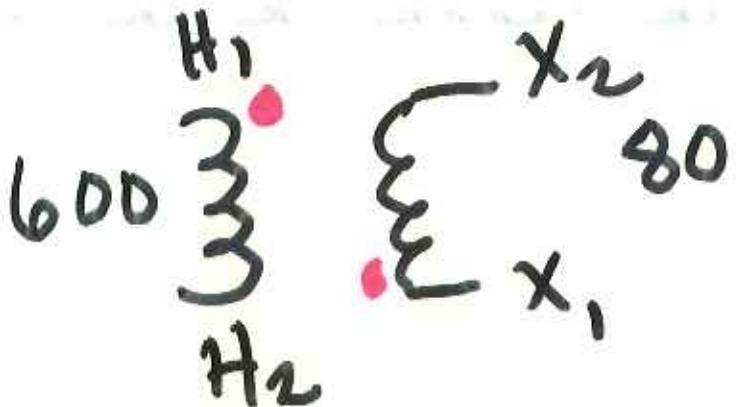
V_{OUT}

720 or 2780

600

720 or 480

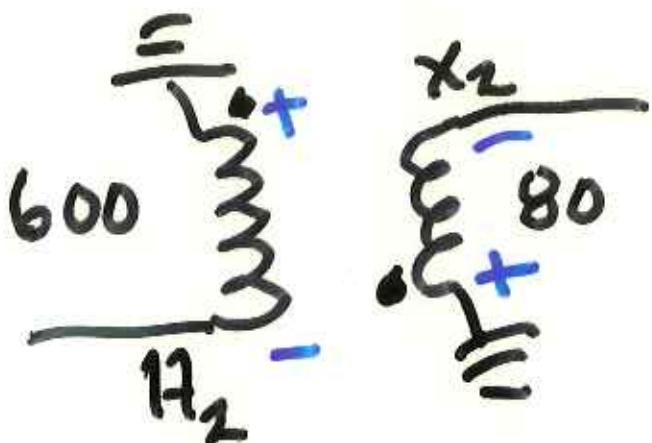




Both sides
are
isolated

$$V_{H1} - V_{X2} = ? \Rightarrow \text{Why?}$$

Short H_1 to X_1 and ground!

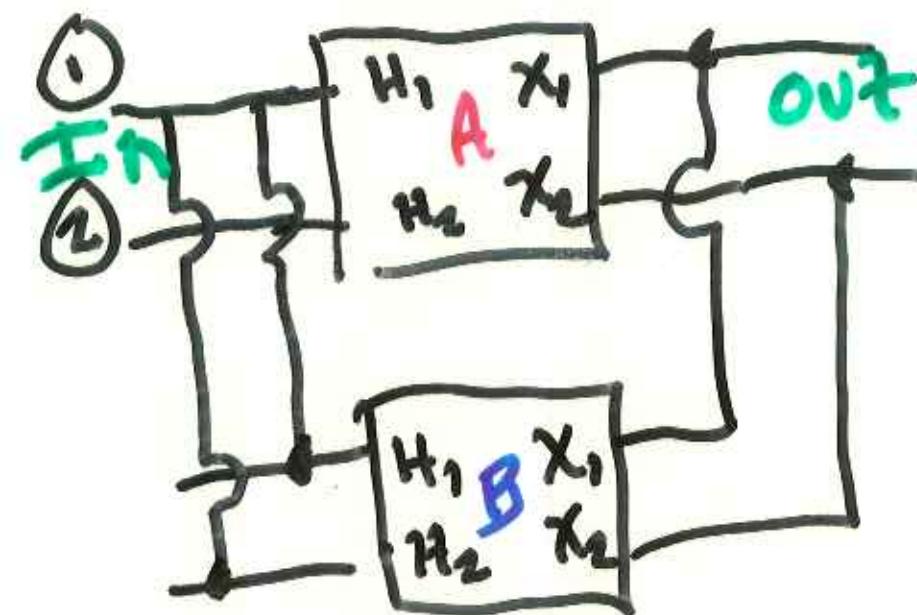


$$V_{H2} - V_{X2} = ?$$

- 520 Why

Two Parallel Transformers

Fig 10.34 Pg 211



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

What if electrician
miswires

$$H_1^A \rightarrow H_2^B$$

$$H_2^A \rightarrow H_1^B$$

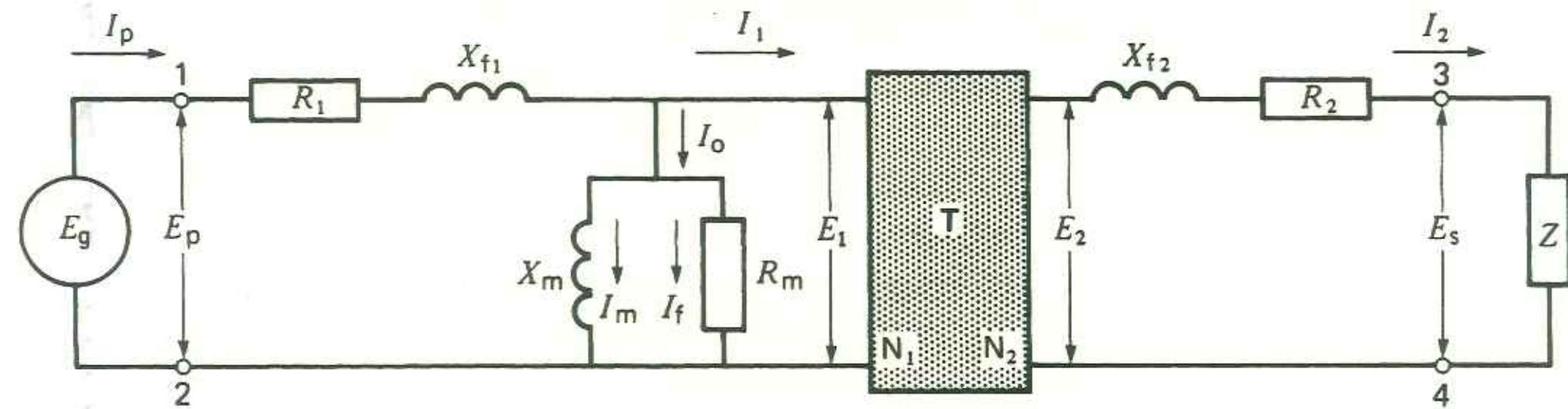
e.g. reversed the terminals?

Short circuit

Less Power TO THE People



How to determine / measure
transformer
those parameters?

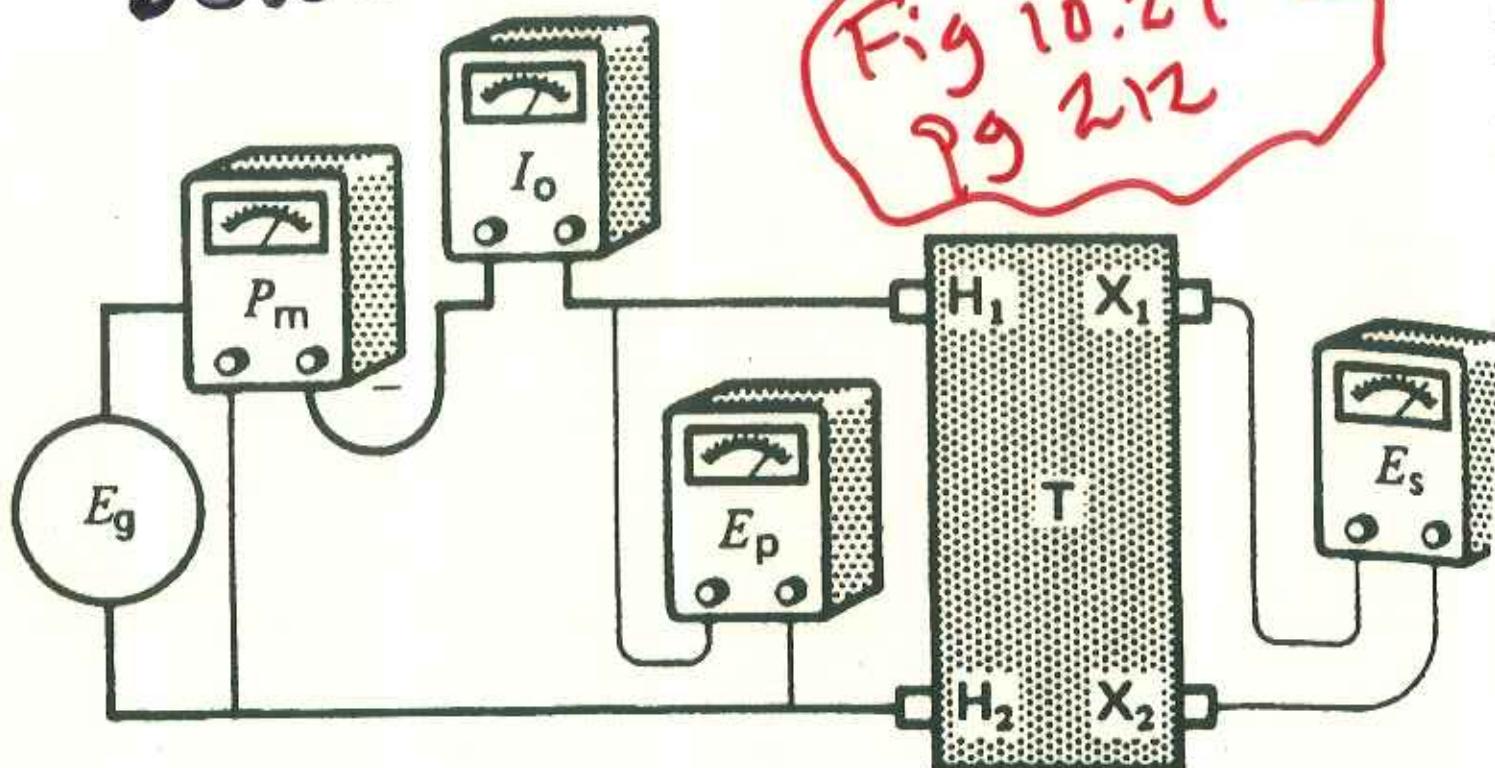


$X_m R_m$ — Short Circuit Test?

Open Ckt Test?

(X_e) (X_f) R_w measured by?
Below is which test?

Fig 10.21
pg 212



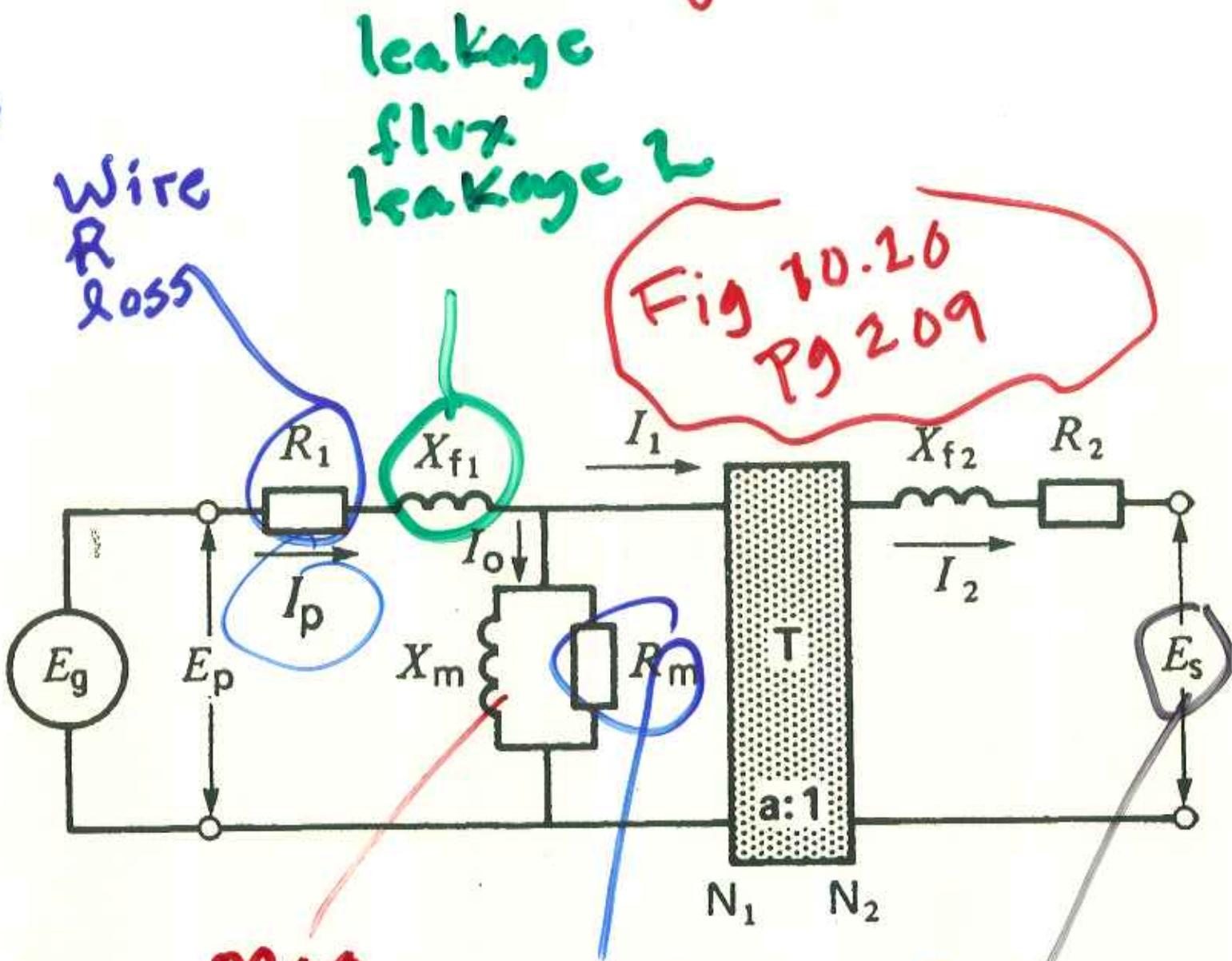
Open Ckt Test

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

Role of power motor

13

Simple Eq Circuit

10
22

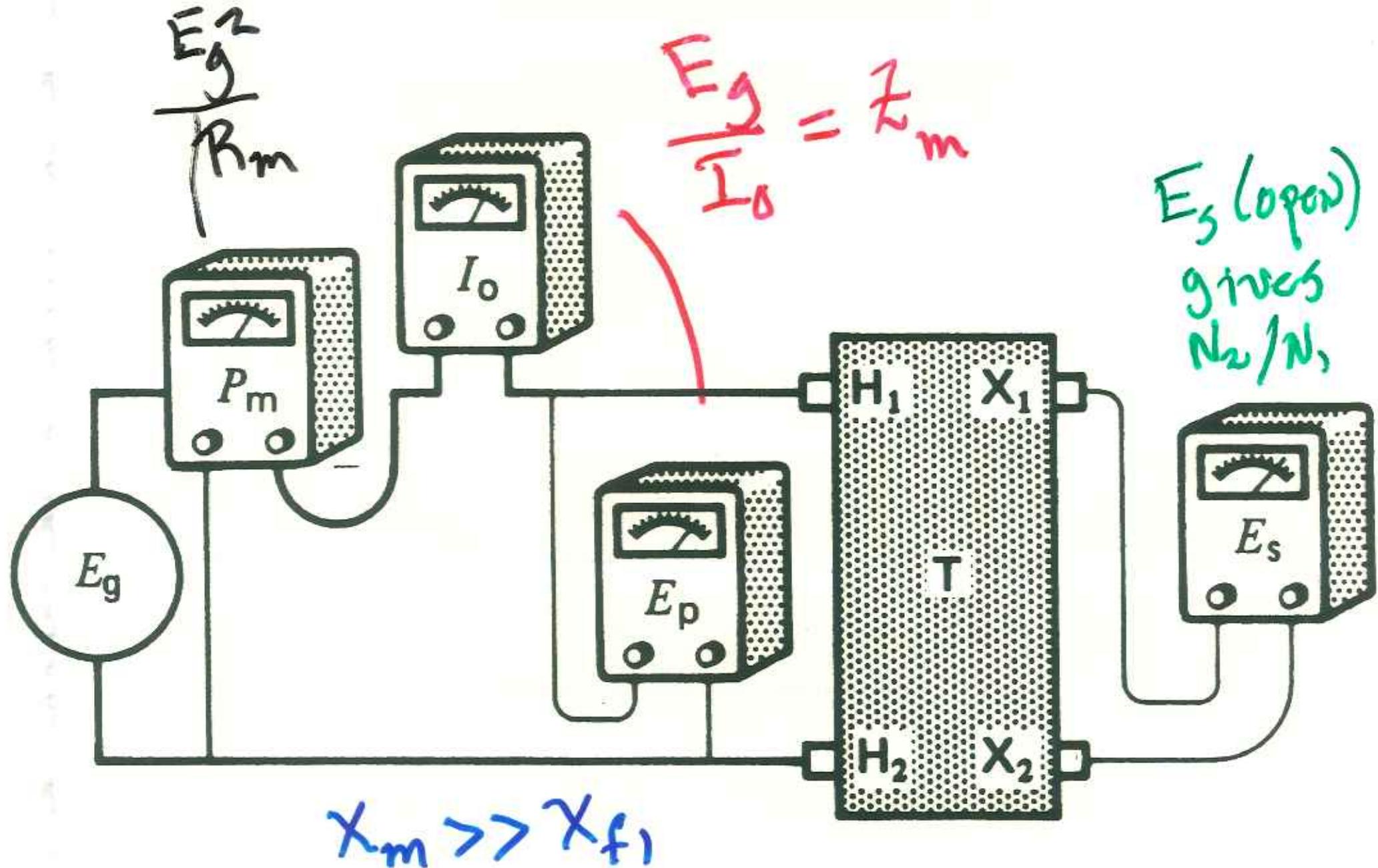
Mag
i
drawn
from E_g
at 90°

Hysteresis and
Eddy i
Losses

$I_p = 0$ for open load?

Open
 $I_1 = ?$

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

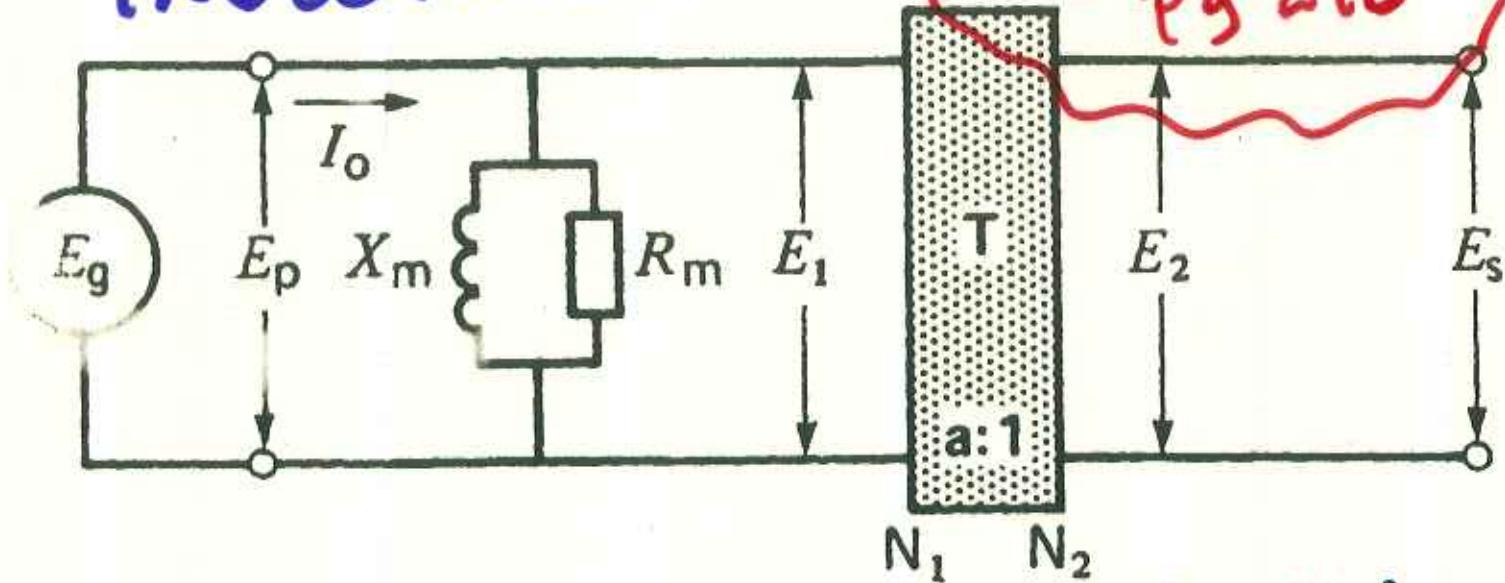


24 Open Circuit Trf. Test

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

We can measure L_m the transformer magnetizing inductance

Fig 10.2010
Pg 210



We measure R (Core loss)

2d
a

at which test below?

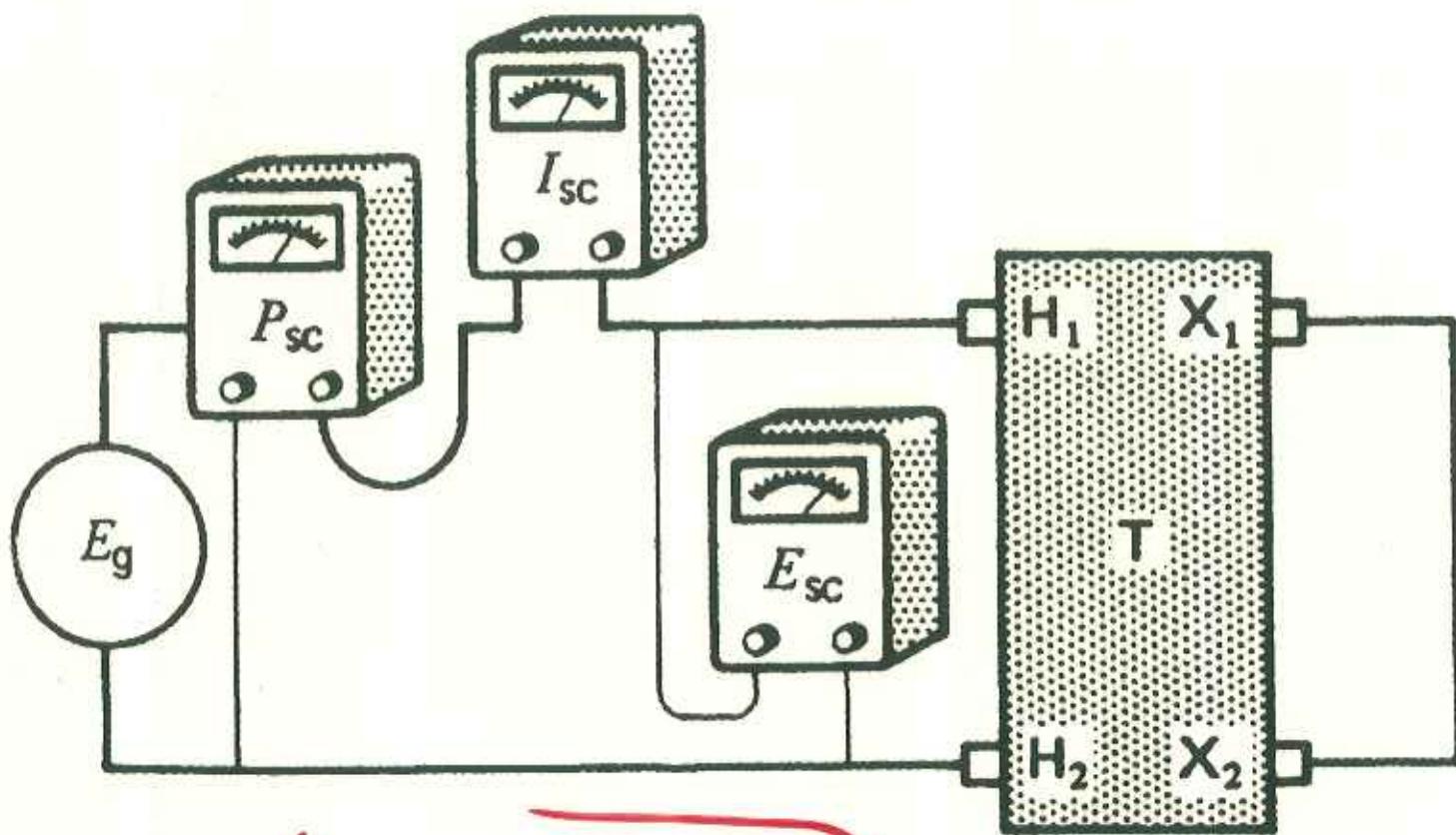


Fig 10.28
pg 213

$$X_e = ?$$

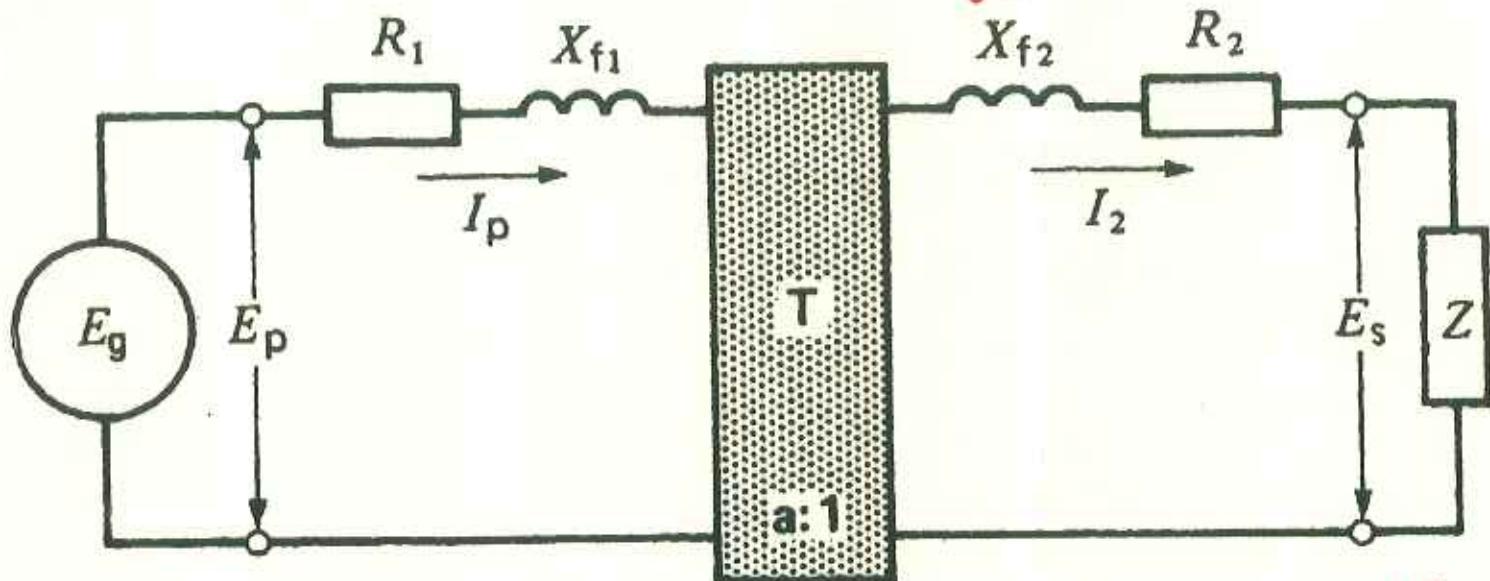
$$R_{wire} = ?$$

25 Short Circuit (Full load)
Transformer Measurement

We measure: $I_p \gg I_{lm}$

① Wire Resistances

Fig 10.22
pg 270

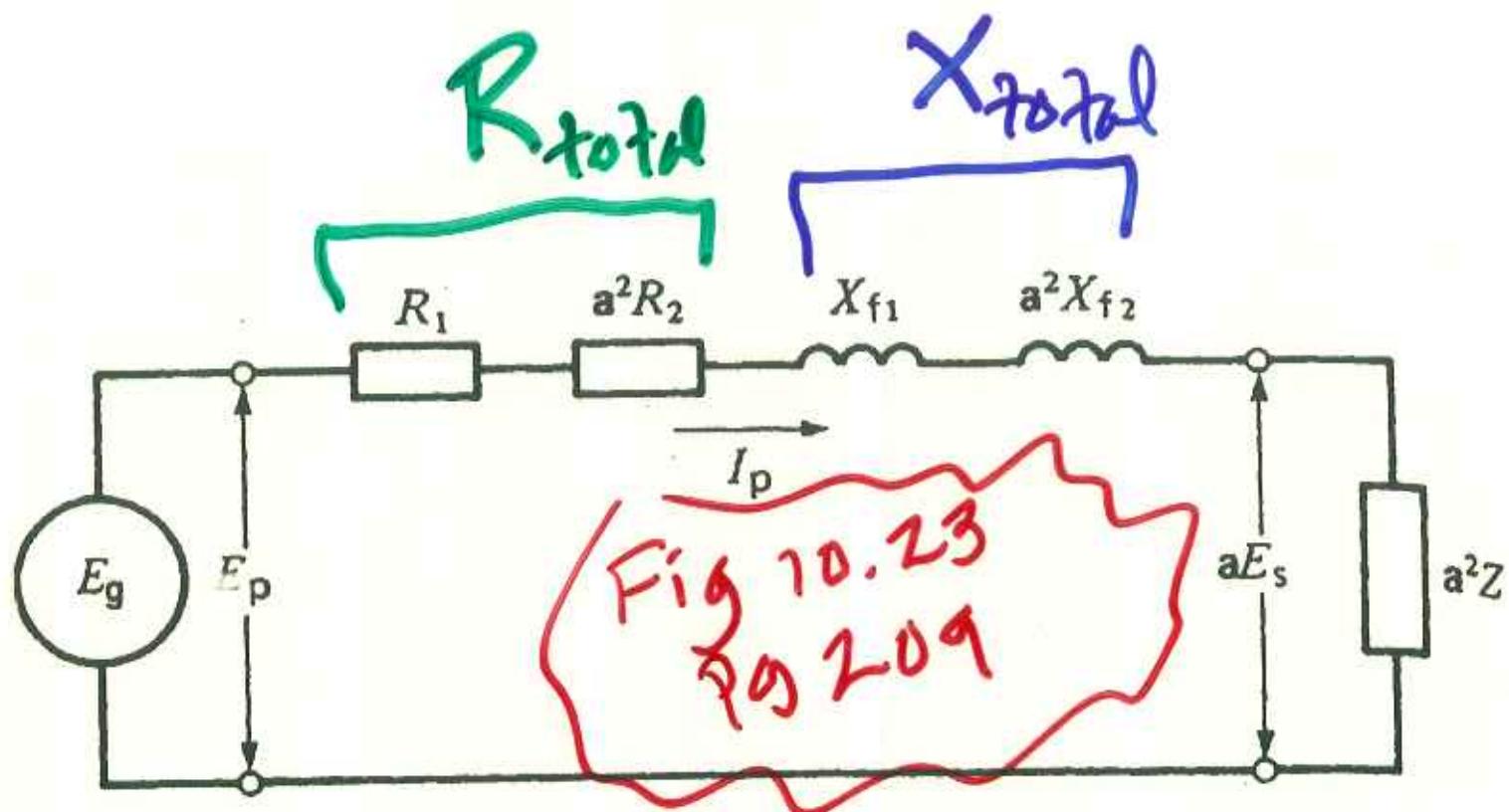


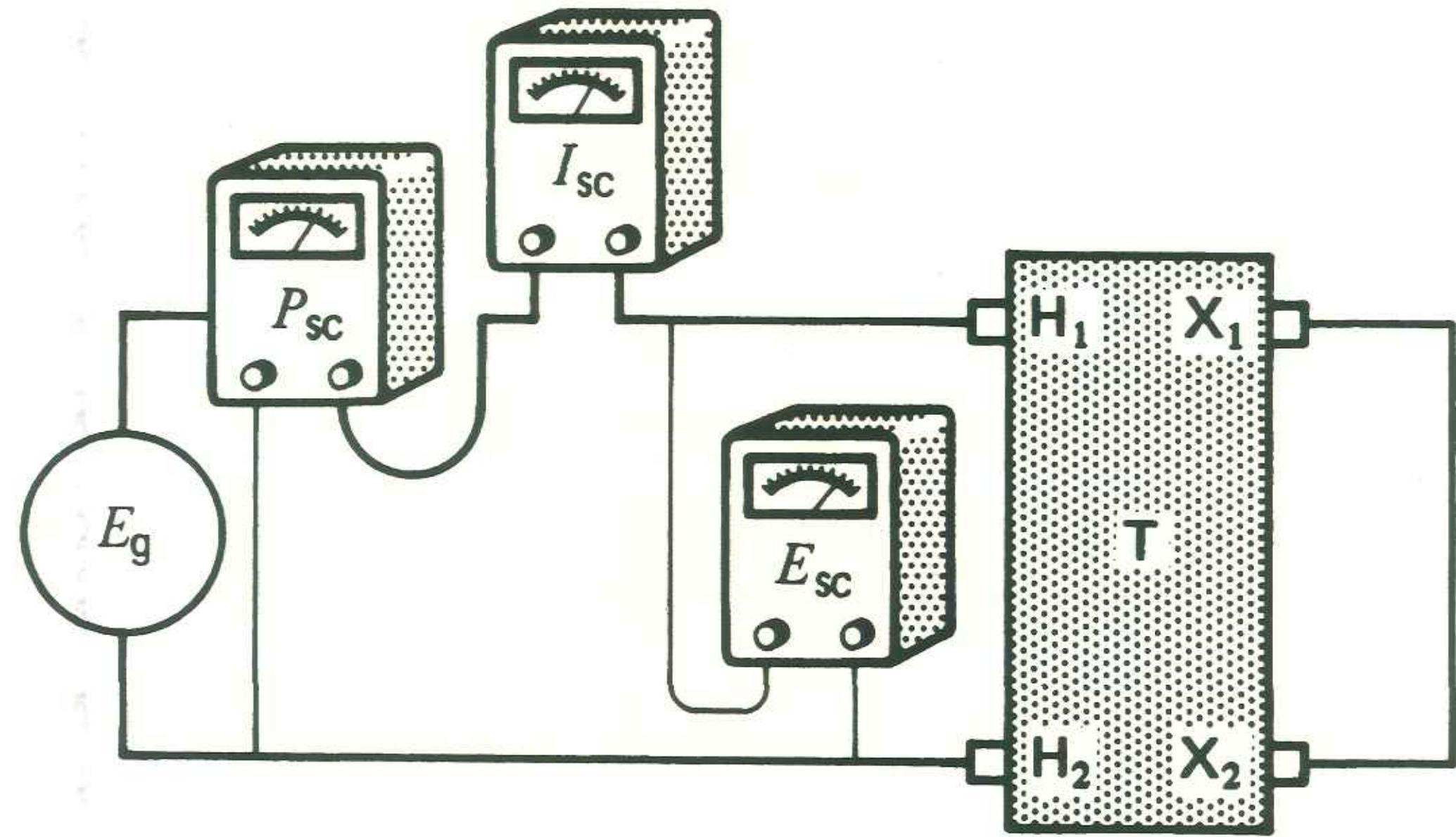
2. Leakage Inductance: X_{f2}
 $Z_{load} \rightarrow 0$ I_{sec} is I_{max}

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

$$R_1 + \tilde{a}^2 R_2$$

$$X_{f1} + \tilde{a}^2 X_{f2}$$





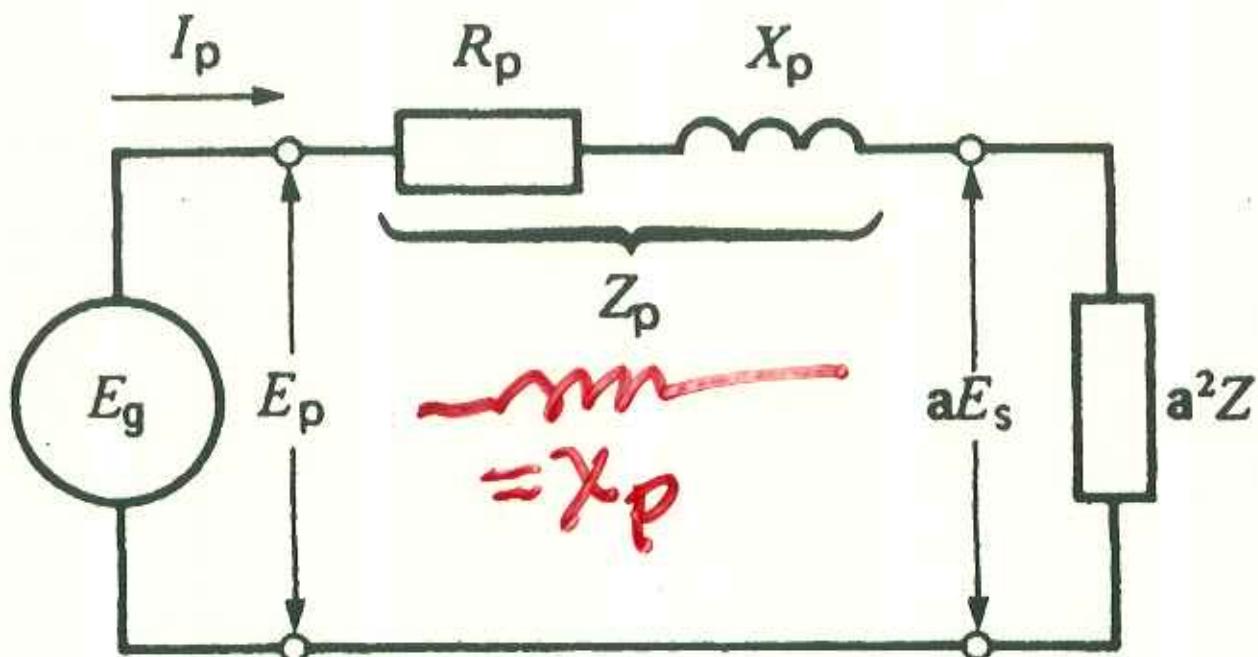
30

In power transformers

$X_p \gg R_p$ (low P loss)

We design for P this case
 $S > 500 \text{ kVA}$ Trf

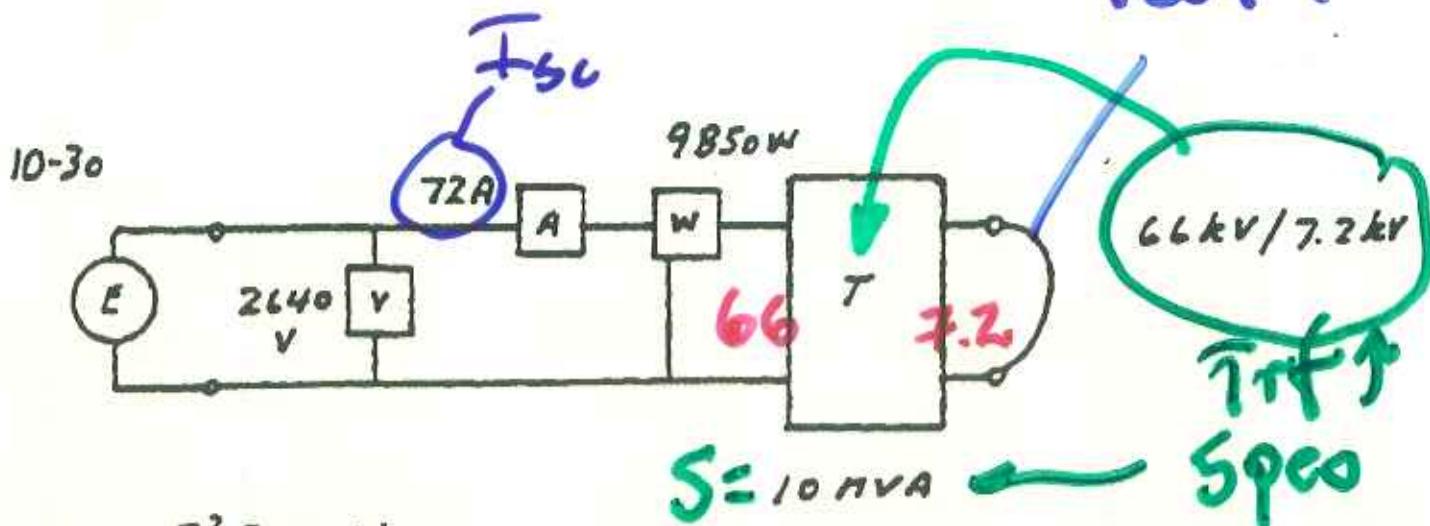
even
 $S > 300 \text{ kVA}$



Often at full load only
 X_p represents the entire
 transformer

IN $\xrightarrow{\text{m}}$ X_p (in pu) OUT

sct



a. $I^2 R_p = W$

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

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

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

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

c. percent impedance = $\frac{36.67}{435.6} \times 100 = 8.4\%$.

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

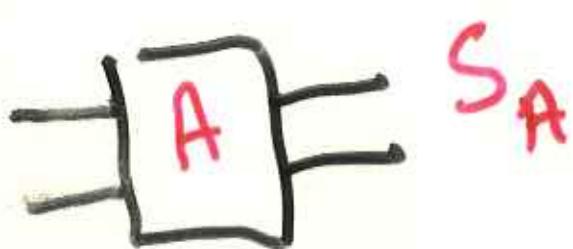
$$R_p = R_{w1} + n^2 R_{w2}$$

$$X_p = X_{q1} + n^2 X_{s2}$$

Why trf in 11?

Need I_{max} for load but ^{NO} trf

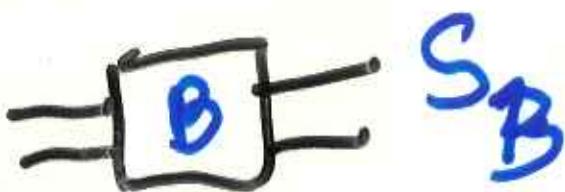
- Need more I for load
using existing transformers
- S (one trf) limited
but two $S_T = S_1 + S_2$



S_A

How to wire?

Which is HV?
LV.



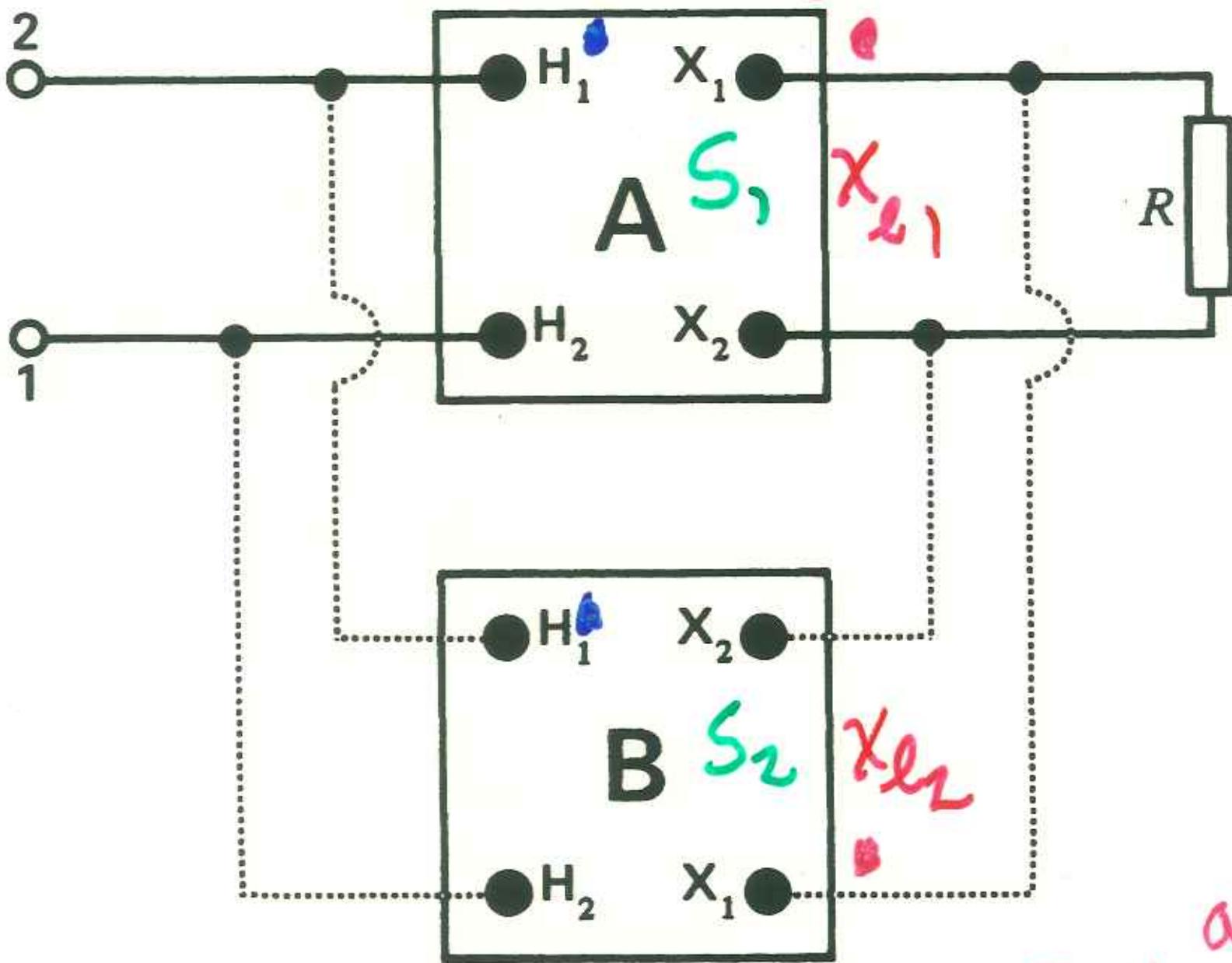
S_B

Issues for "i sharing"?

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

$$S_A \neq S_B$$

Note Phasing is Key
Wiring



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

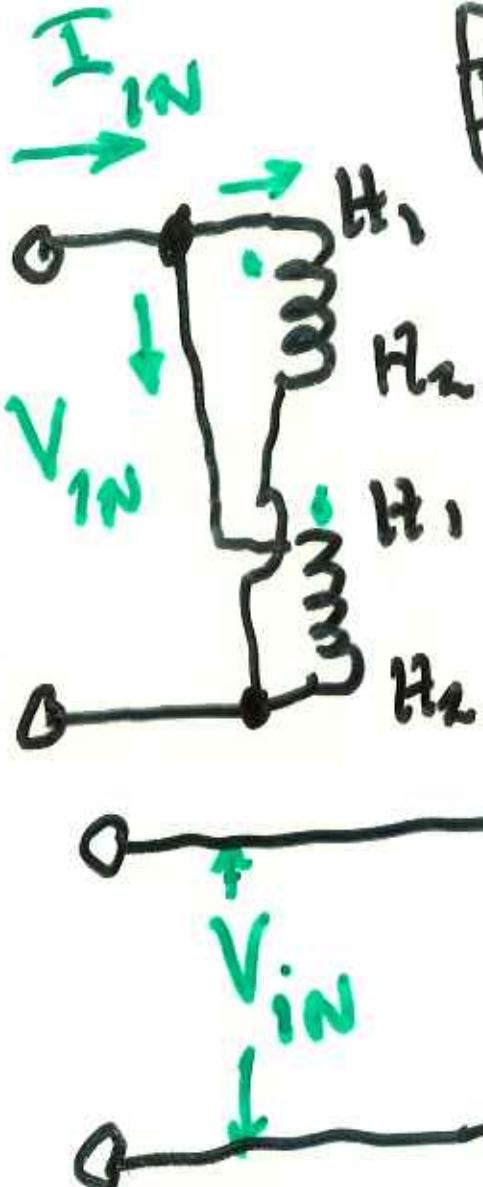
Wire Trf in Parallel

Why?

Same S ?

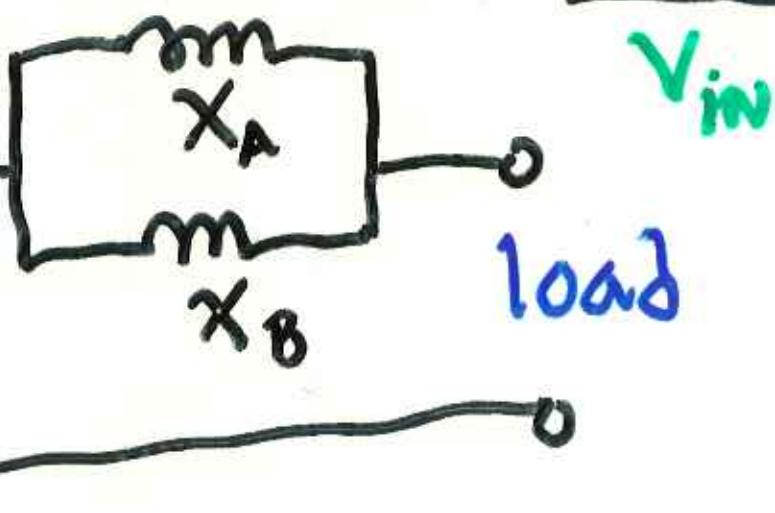
Different S ?

Identical Trf



$$I_{in}^{max} = ? \quad S^{max} = ?$$

Each trf can handle $\frac{S_{max}}{V_{in}} = I_{in}$



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

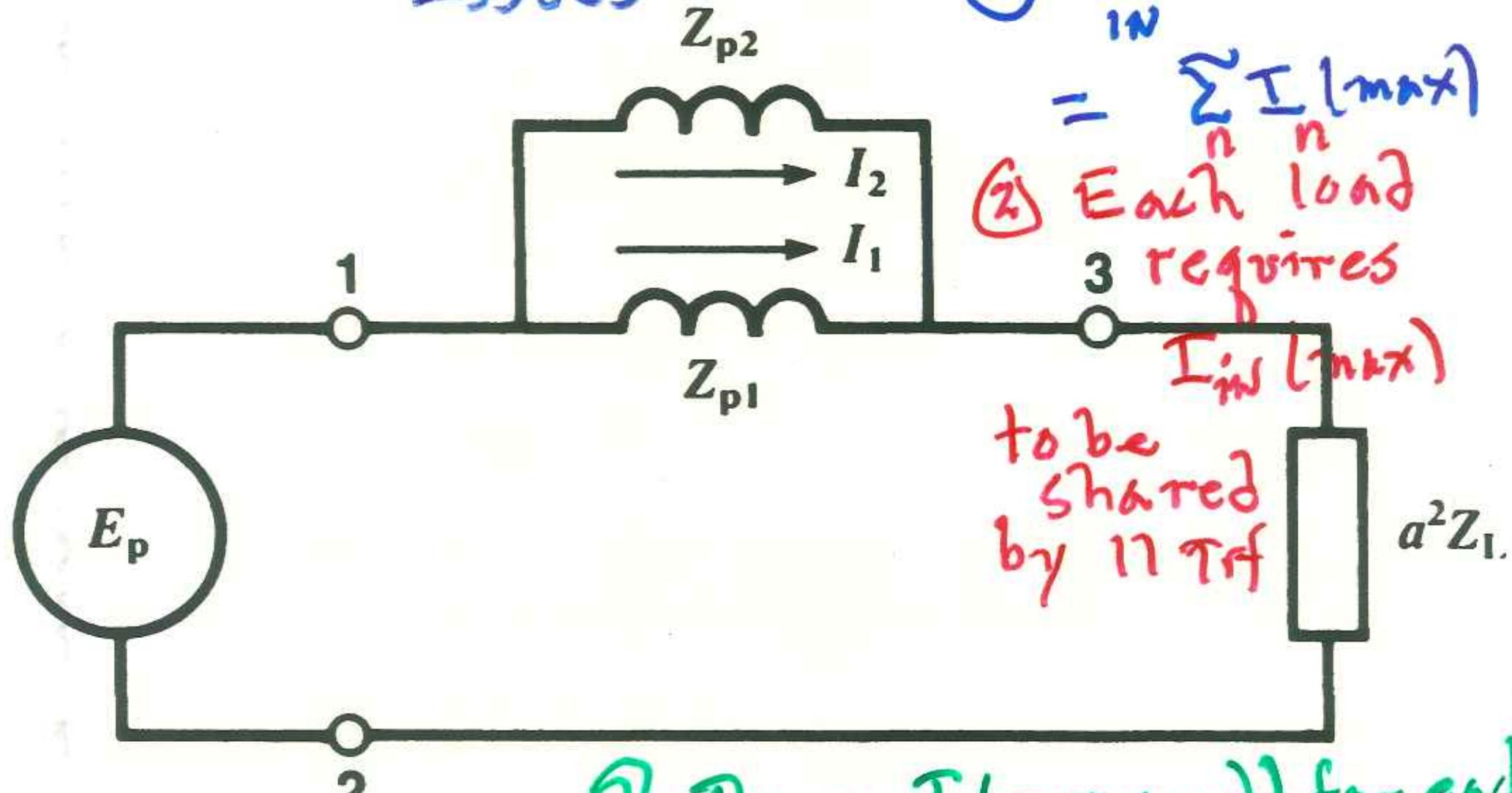
Issues are?

$$\textcircled{1} I_{IN}^{\text{max}} = \sum_n I_n^{\text{max}}$$

\textcircled{2} Each load
3 requires

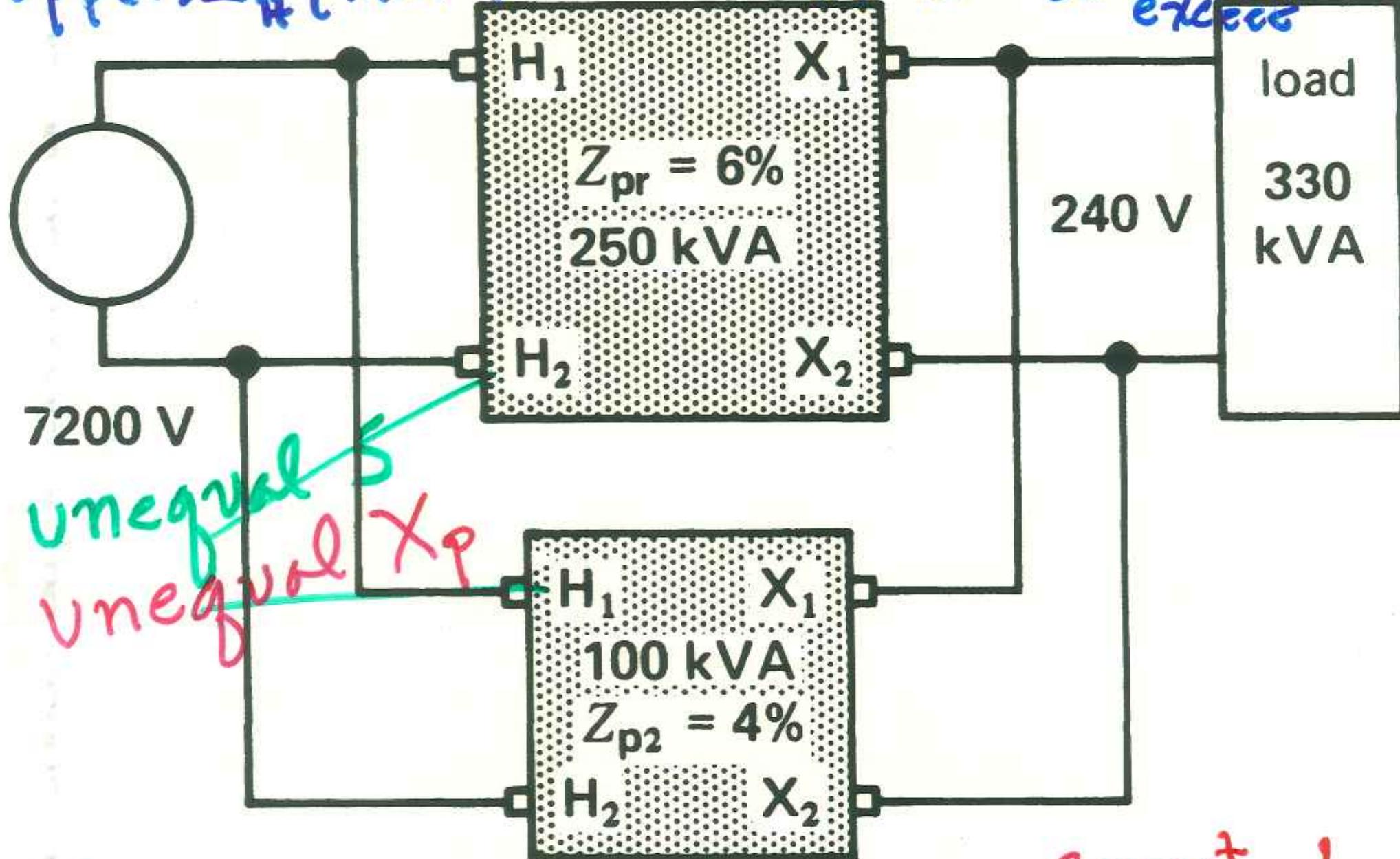
$$I_{IN}^{\text{max}}$$

to be
shared
by 11 Trf

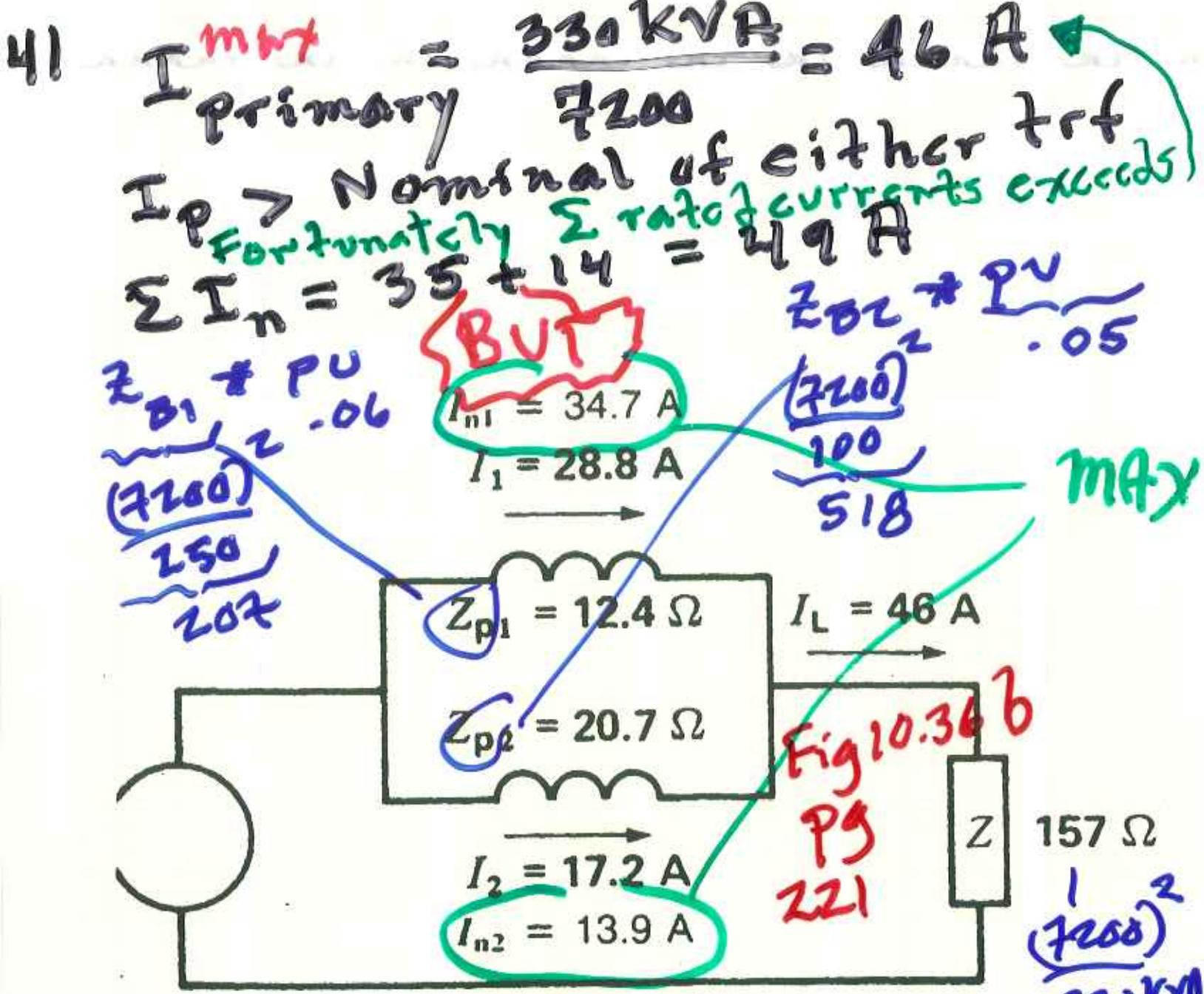


? Does $I_{\text{L required}}$ for each
Trf ever exceed
 $\frac{I_{\text{L rating}}}{I_{\text{L max}}}$?

upper: $I_H(\text{max}) = \frac{250 \text{kVA}}{7200} = 35$ Cannot exceed



lower: $I_H(\text{max}) = \frac{100 \text{kVA}}{7200} = 14$ Cannot exceed!



$I_p = 46 \text{ A}$ divides as

$$I_1 = \left[\frac{20.7}{12.4 + 20.7} \right] 46 = 28.8 \text{ A}$$

OK $L I_n = 35$

$$I_2 = \left[\frac{12.4}{12.4 + 20.7} \right] 46 = 17 \text{ A} \quad ? \text{ OK}$$

compared to?
 rated current?

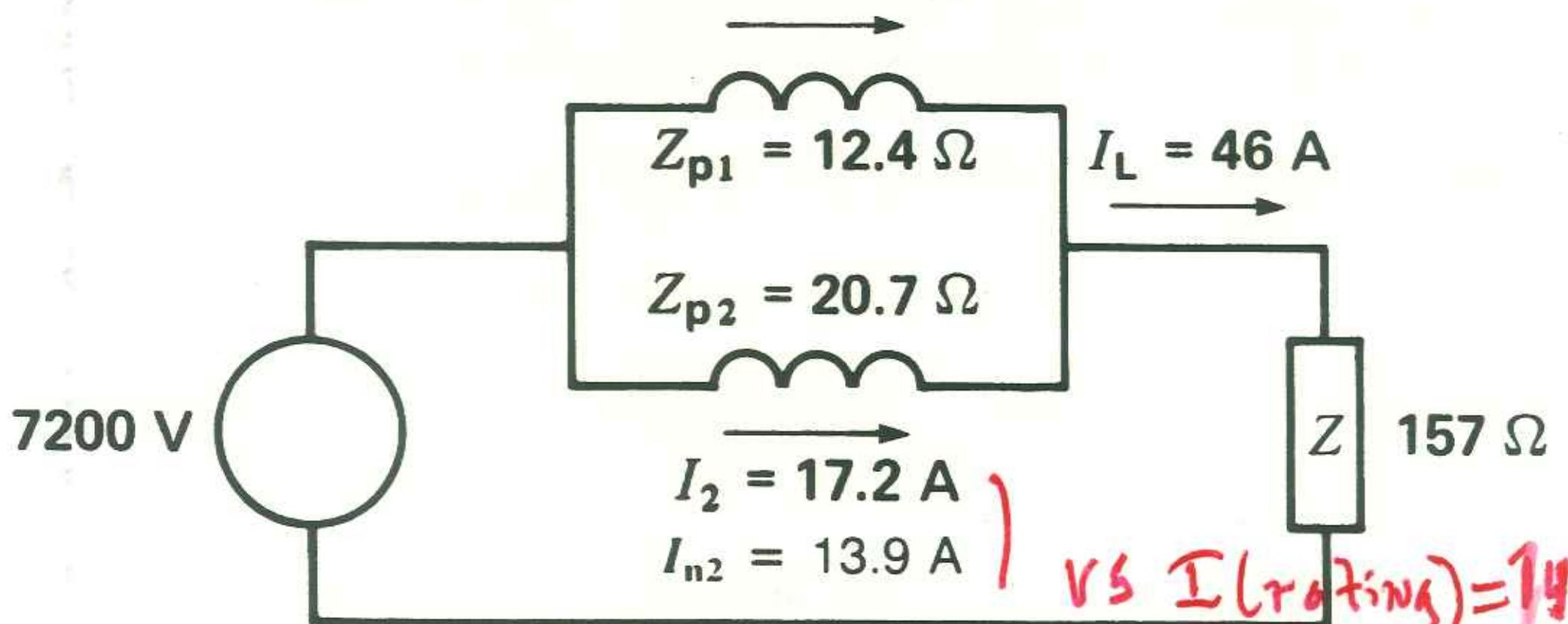
NG
 \geq
 $I_{n2} = 14$

$$I_R = 14 \text{ A}$$

$$I_{n1} = 34.7 \text{ A}$$

$$I_1 = 28.8 \text{ A}$$

$$\text{vs } I(\text{rating}) = 35$$



$$\text{vs } I(\text{rating}) = 14$$

Whoaa! over
limit 😕

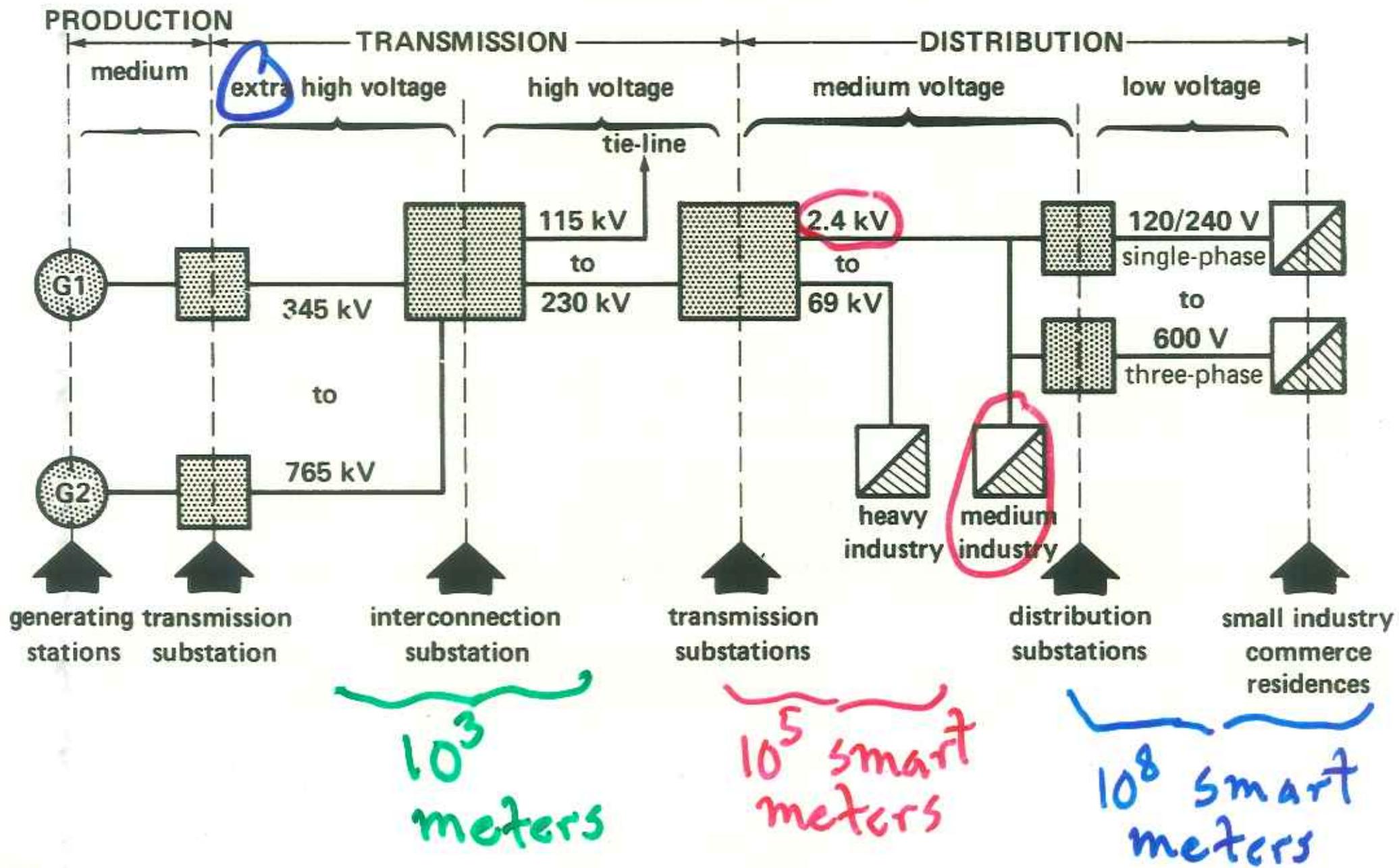
Electric Utility Companies

- 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**



Why use DC?
When employ DC?

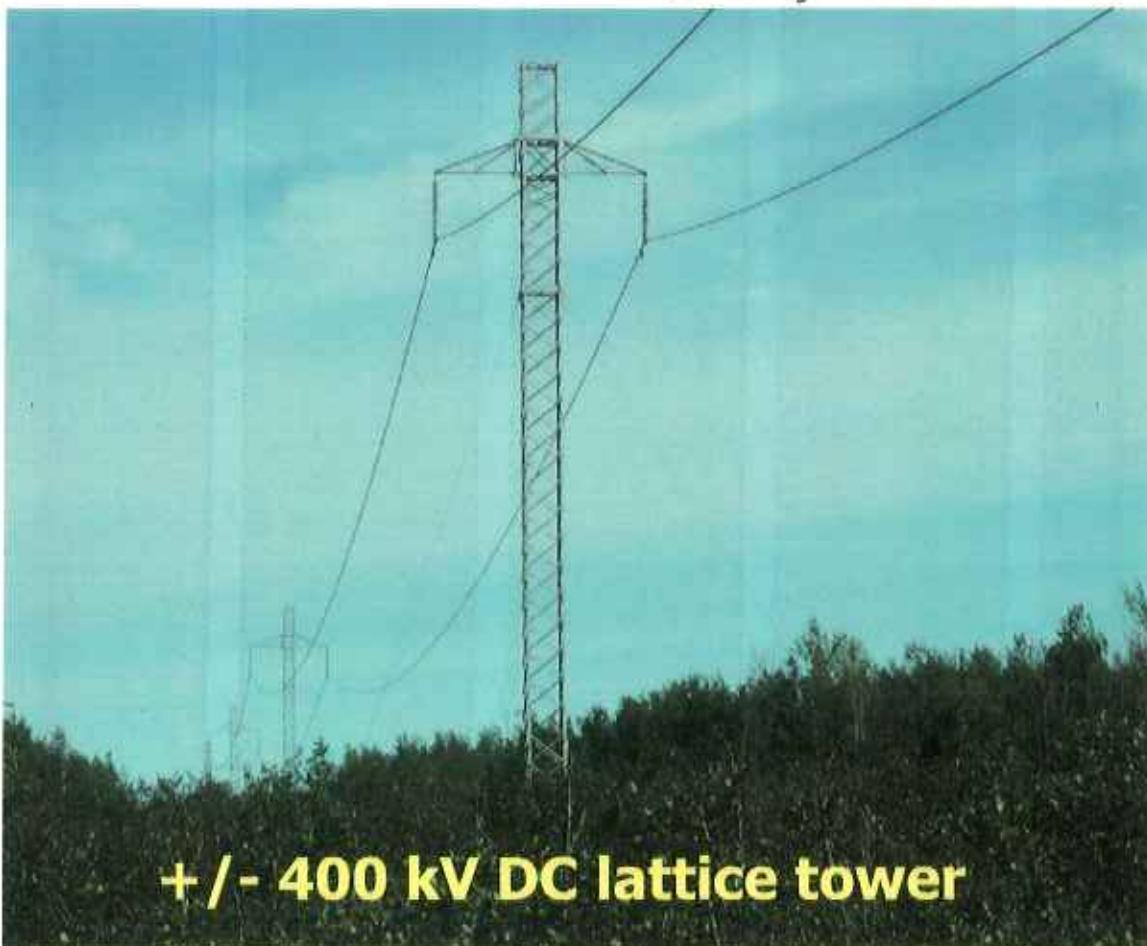


Fig 25.42 Pg 735

