Cast Copper Rotors Efficiency Test Results

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What is 1% motor efficiency worth?

- **Two-thirds (2/3) of all electricity is used to run motors**
- **Motors use 2 Trillion KWHr per year**

1% better motor efficiency would save:

- **20 Billion KWHr per year**
- **$1.4 Billion at 7 cents per KWHr**
- **Equivalent to 36.5 Million barrels of oil**

Direct Copper to Aluminum Comparison

- 7 rotors tested in the same stator
- All tested on the same dynamometer
- Copper rotors compared to a large data base of previous motor tests
- Aluminum rotor motors averaged into a “standard” motor

IEEE – 112B Efficiency Test

- **Iron core loss** – Magnetic losses in lamination stack, inductance and eddy current losses
- **Stator resistance** – current losses in windings
- **Rotor resistance** – current losses in rotor bars and end rings
- **Windage and friction** – mechanical drag in bearings and cooling fans
- **Stray load losses** – magnetic transfer loss in the air-gap between rotor and stator

IEEE Loss Segregation Test Results

	Watts Loss			
	Al	Cu	Diff.	Percent
Stator resistance	507	507	0	0%
Iron core loss	286	286	0	0%
Rotor resistance	261	157	-104	-40%
Windage / friction	115	72	-43	-37%
Stray load loss	137	105	-32	-23%
Total losses	1306	1127	-179	-14%

IEEE Performance Test (1)

	Al	Cu	Diff.	Percent
Efficiency	89.5%	90.7%	+1.2	+1.4%
Losses	10.5%	9.3%	-1.2	-11.4%

- Added 1.2 percentage points to the nameplate
- Reduced losses by 11.4%

	Al	Cu	Diff.	Percent
Power Factor	81.5%	79.0%	+2.5	-3.0%

- Does not directly affect power usage
- Power factor corrected on a whole plant basis

IEEE Performance Test (2)

	Al	Cu	Diff.	Percent
Full Load RPM	1760	1775	+15	+1%
Slip	2.22%	1.37%	-0.85	-38%

- Slip is the difference between the full load speed of the rotor/shaft versus the synchronous speed of the rotating electrical field in the stator – 1800 RPM
- Copper rotor motor is a very “stiff” motor
- Implies a very good motor on variable speed drives for Servo-like performance
- Potential problems on Centrifugal loads
- Fans and pumps follow the Cube Law: 1% increase in speed = 3% increase in power input

IEEE Performance Test (3)

	Al	Cu	Diff.	Percent
Temperature rise	64.9C	59.5C	-4.5C	-7%

- Affects life expectancy of the motor
- For every 10 degrees C hotter a motor runs, life can be reduced in half
- With nearly 5 degrees C cooler running, Copper rotor motors could increase life expectancy by 50%
- Similar results have been seen in premium efficiency motors since their introduction 20 years ago

Torque Issues

	Pound Feet			
	Al	Cu	Diff.	Percent
Starting Torque	58.2	37.0	-21.2	-36%
Breakdown Torque	152.0	125.9	-26.1	-17%
Locked Rotor	69.0	65.0	-4.0	-6%

- Down from historically very high levels
- Still within NEMA minimum requirements
- Locked rotor torque still very good
- Can be corrected with modification to the rotor slot shape

Copper Rotor Consistency

- **Copper rotor motors averaged 90.7% efficiency**
  Range: 90.6% – 90.8%
- **Copper rotor losses averaged 157 Watts**
  Range: 153 Watts – 167 Watts
- **Process variables had no predictable effect on final test results**
- **No balancing weights were required**
- **This is a very robust process with consistency not seen in current rotor die casting methods**

Additional Implications

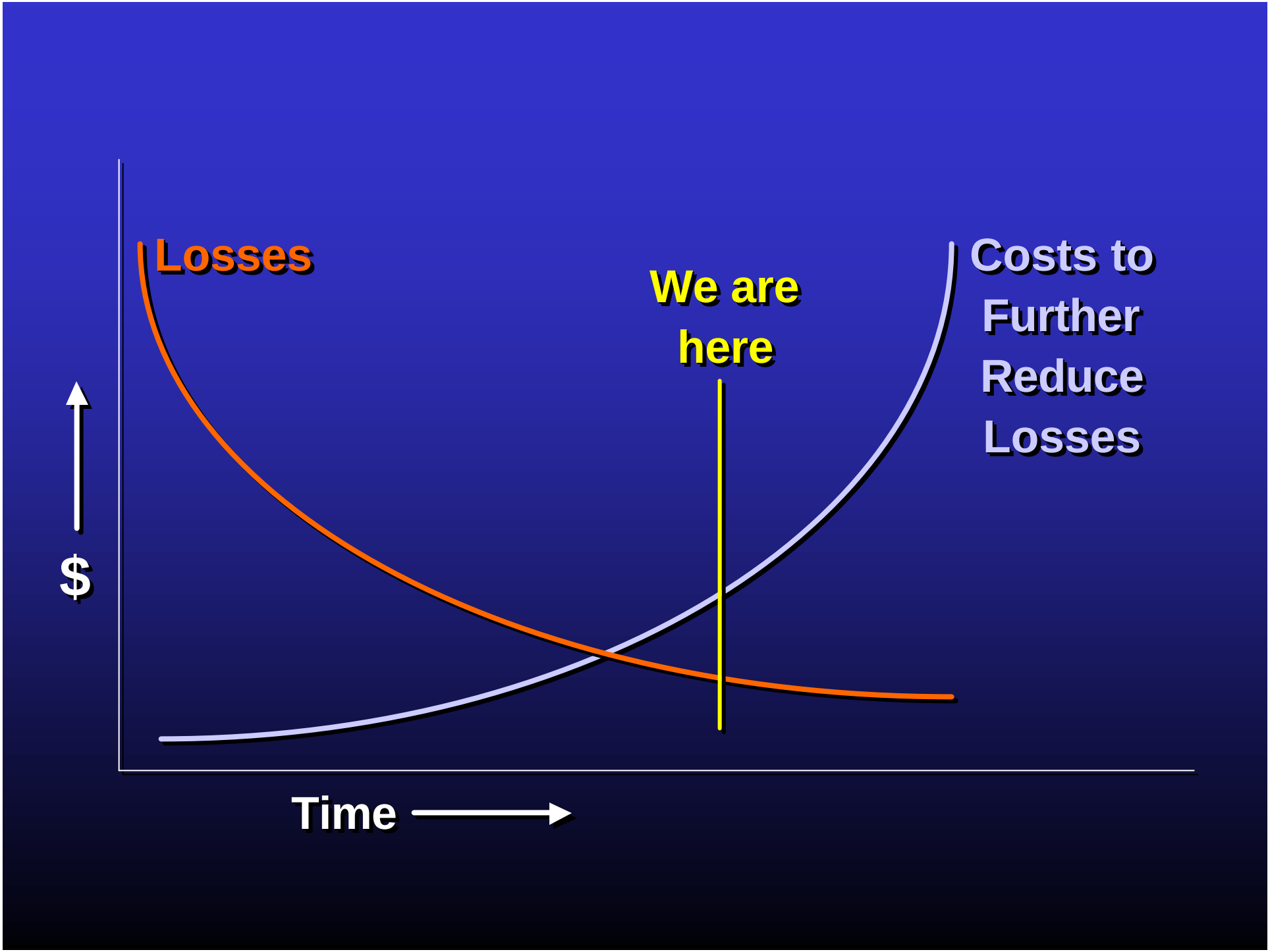
- **Higher efficiency in the same stack length**
- **Same efficiency in a reduced stack length Offsetting material cost differences**
- **Some combination in between**
- **Elimination of balancing procedure in production**
- **Elimination of “safety factor” extra stack length to compensate for rotor irregularities**

Motors designed around a Copper rotor

Tests of an "optimized" Copper motor

- **Rotor losses** **-40%**
- **Total losses** **-23%**
- **Temperature rise** **-70%**
- **Efficiency** **+1.6%** **90.9% vs. 92.5%**

Stator windings and iron core were modified from standard motor design to gain best possible results


Losses
We are here
Costs to Further Reduce Losses
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Time

20 HP Motor, Past and Future