Industrial Technologies Program

A BestPractices
Training Presentation

U.S. Department of Energy

Motor Systems Assessment Training, Including Use of the Motor Systems Tool Suite



U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

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Department of Energy Information Resources

U.S. DOE Industrial Technologies Program (ITP) BestPractices Website

www.eere.energy.gov/industry/bestpractices

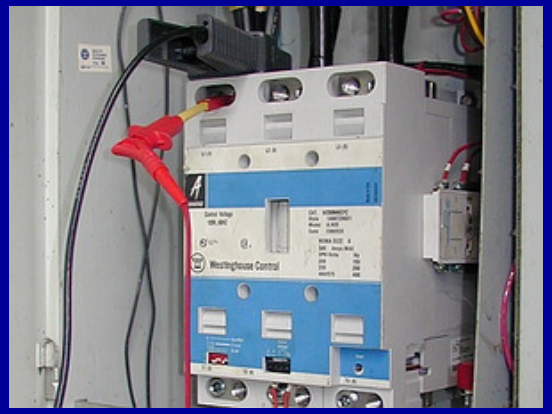
EERE Information Center (877) 337-3463

Or www.eere.energy.gov/informationcenter

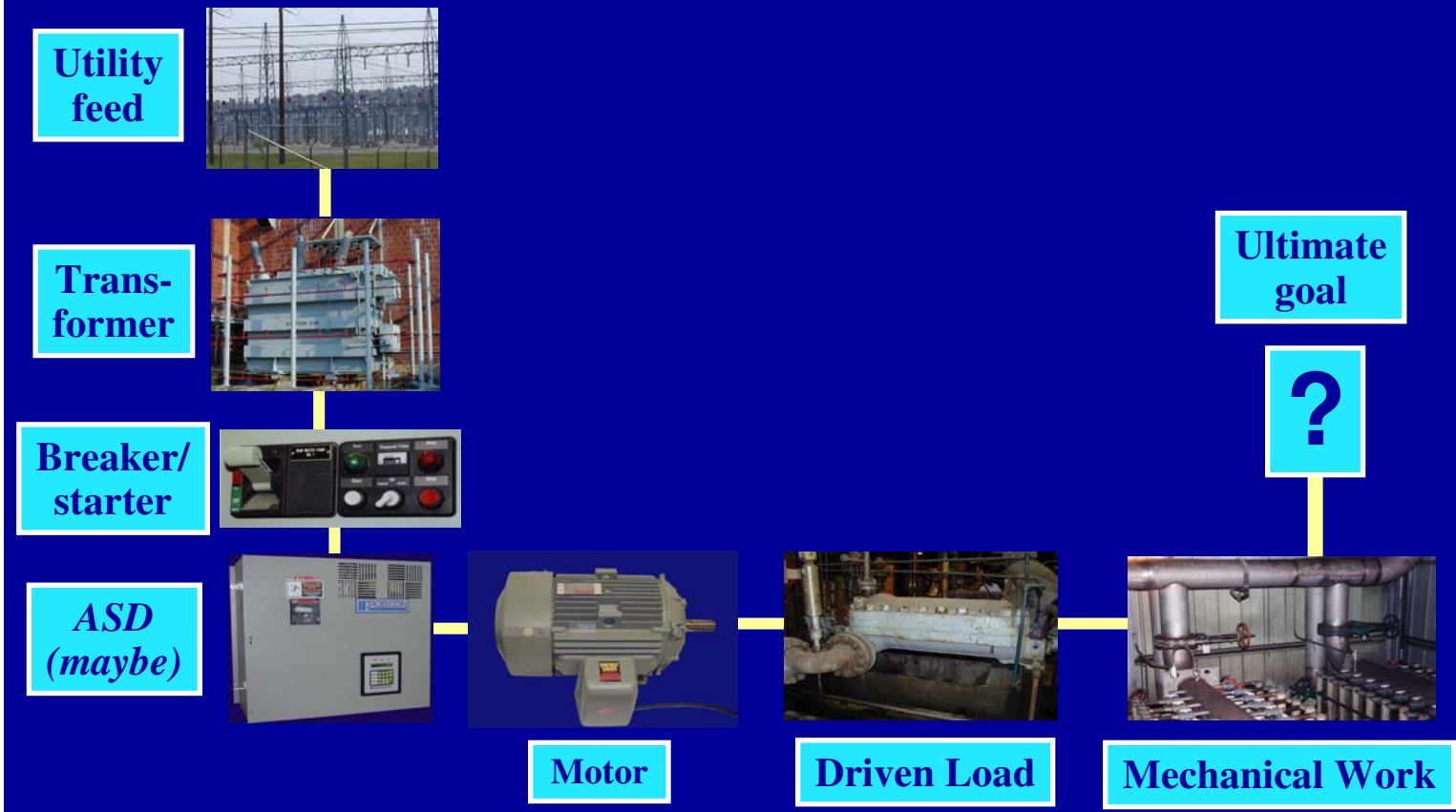
Big Picture Perspectives: Industrial Motor Systems

Industrial motor systems:

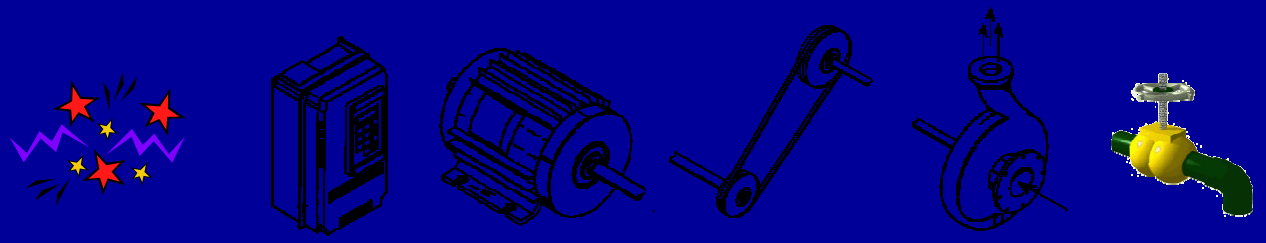
- Are the *single largest electrical end use* category in the American economy
- Account for 23% of U.S. electrical sales.



A motor SYSTEM is the entire energy delivery process, from electric feed to finished product



Typical Motor System Losses



Useful Work

Electrical distribution system losses <1 to 5%

Controller losses <1 to ~5% for ASD

Motor losses 3.5 to >10%

Coupling device losses <1 to >10% for large speed reduction

Driven load losses 30 to 50% for pumps and fans

Load modulation devices 0 to >50%

Industrial Motor System Savings Potential

Industrial motor system energy use can be decreased by 11% to 18% if industries deploy all mature/proven and cost-effective energy efficiency technologies

The total savings potential is 75 to 122 billion kWh/year….Valued at $3.6 to $5.8 billion per year at current industrial rates

Source: 1999 Xenergy Study

What is efficiency?

Efficiency = Output / Input

Efficiency = (Input - Losses) / Input

Efficiency = Output / (Output + Losses)

They're all mathematically equivalent.

NEMA Definitions

"Energy Efficient"

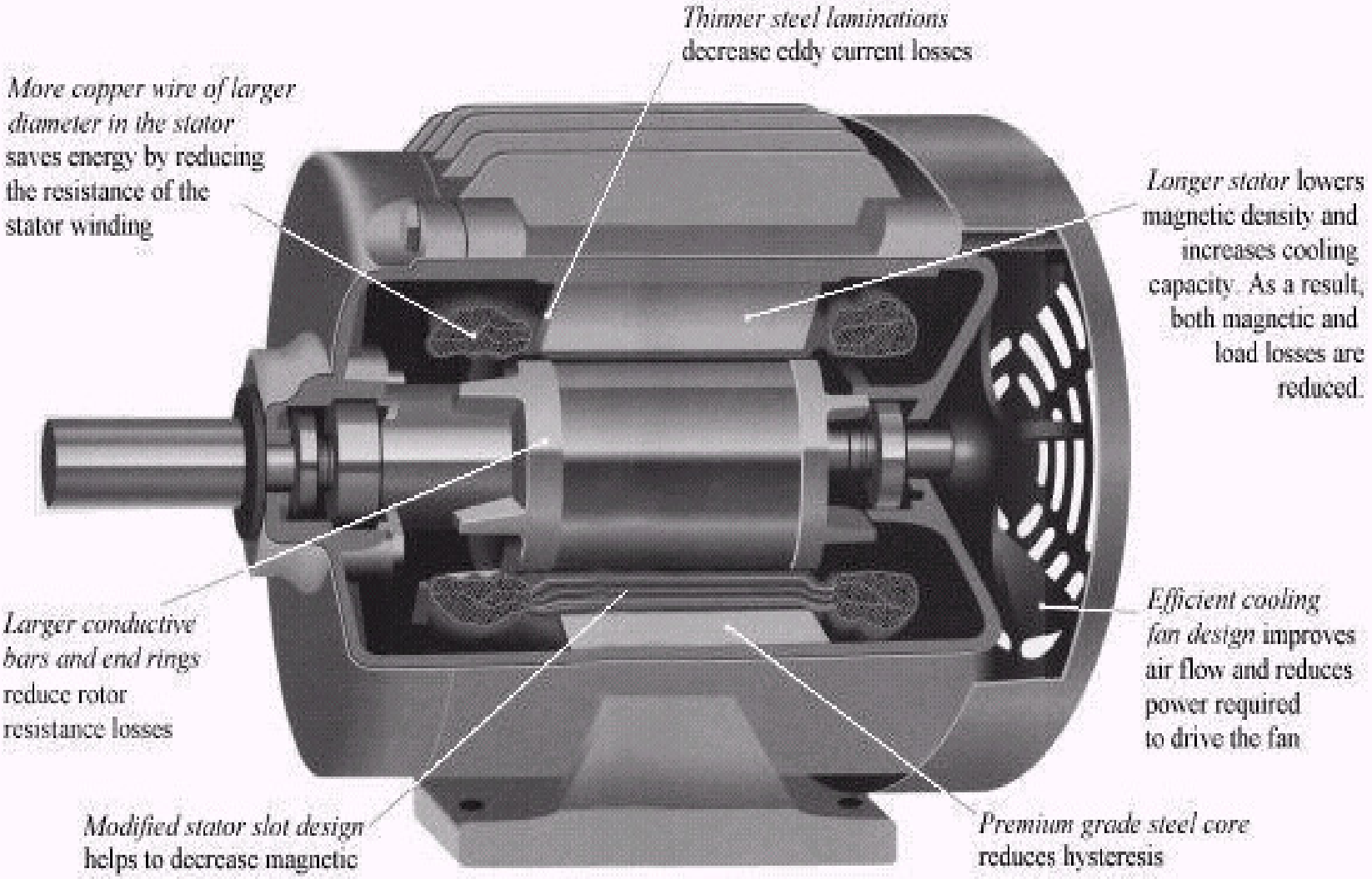
- This covers 3-phase induction motors with efficiencies equal to or exceeding that in table 12-11 of NEMA's MG 1 standard. It pertains to low voltage (<600V) motors from 2-poles to 8-poles and 1-500 HP.

"NEMA Premium™ Efficient"

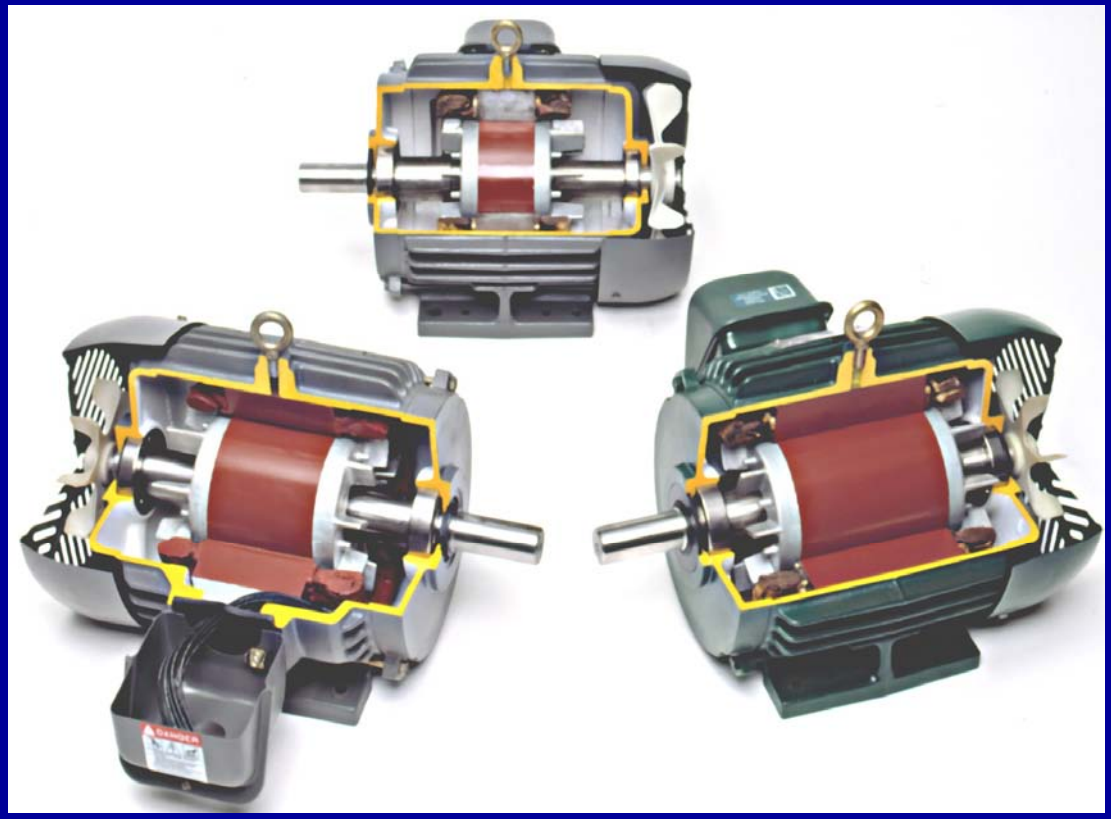
- This covers 3-phase induction motors from 2-poles to 6-poles. It pertains to low voltage motors from 1-500 HP and medium voltage (>600 & <5000V). See http://www.nema.org/premiummotors

To Compare all the motor efficiency standards, see http://www.energy.wsu.edu/ftp-ep/pubs/engineering/motors/EfficiencyStandards.pdf

WHAT MAKES AN ELECTRIC MOTOR ENERGY EFFICIENT?

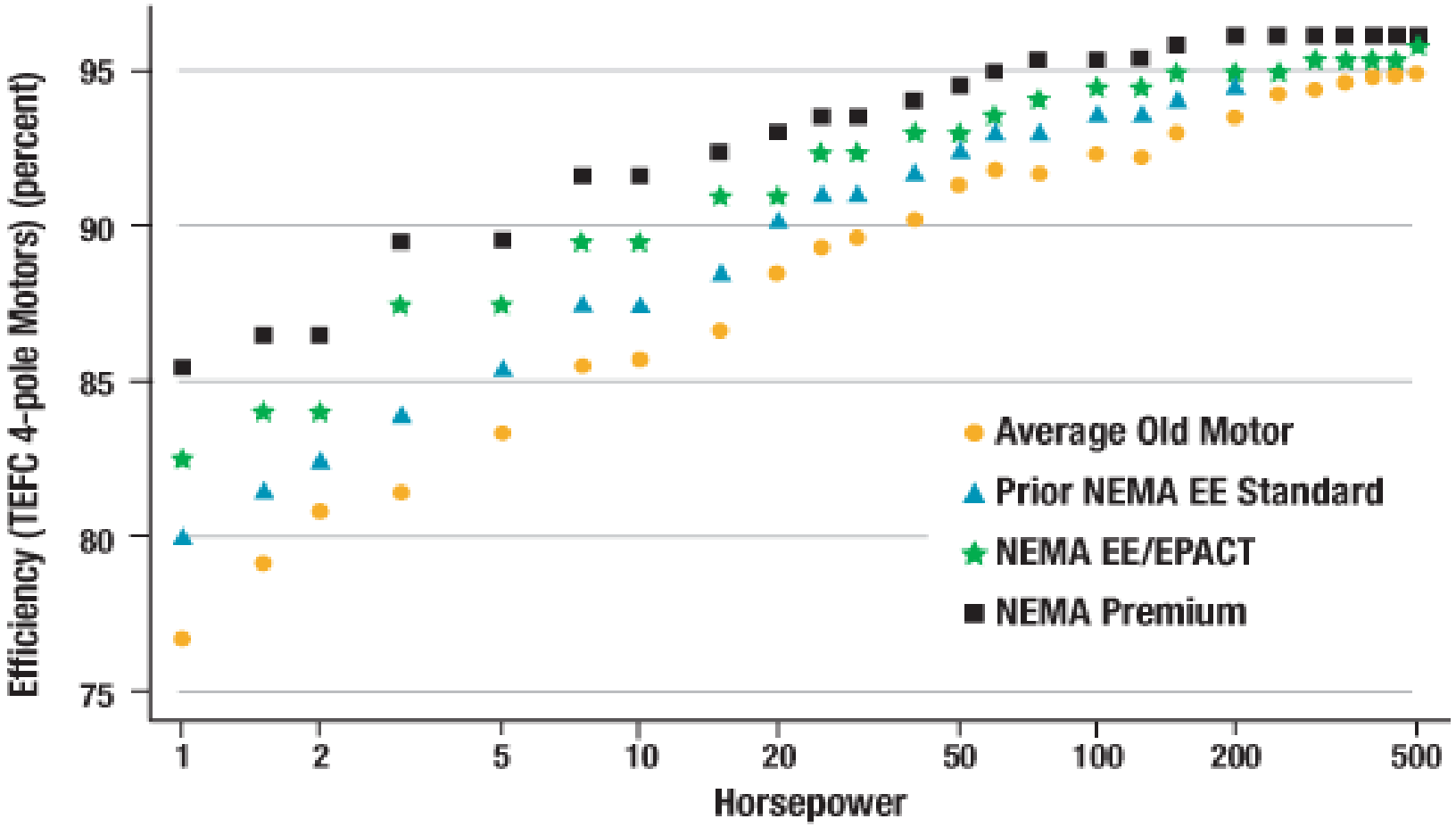


Standard, EE, PE Motors – Amount of Copper, Size of Rotor

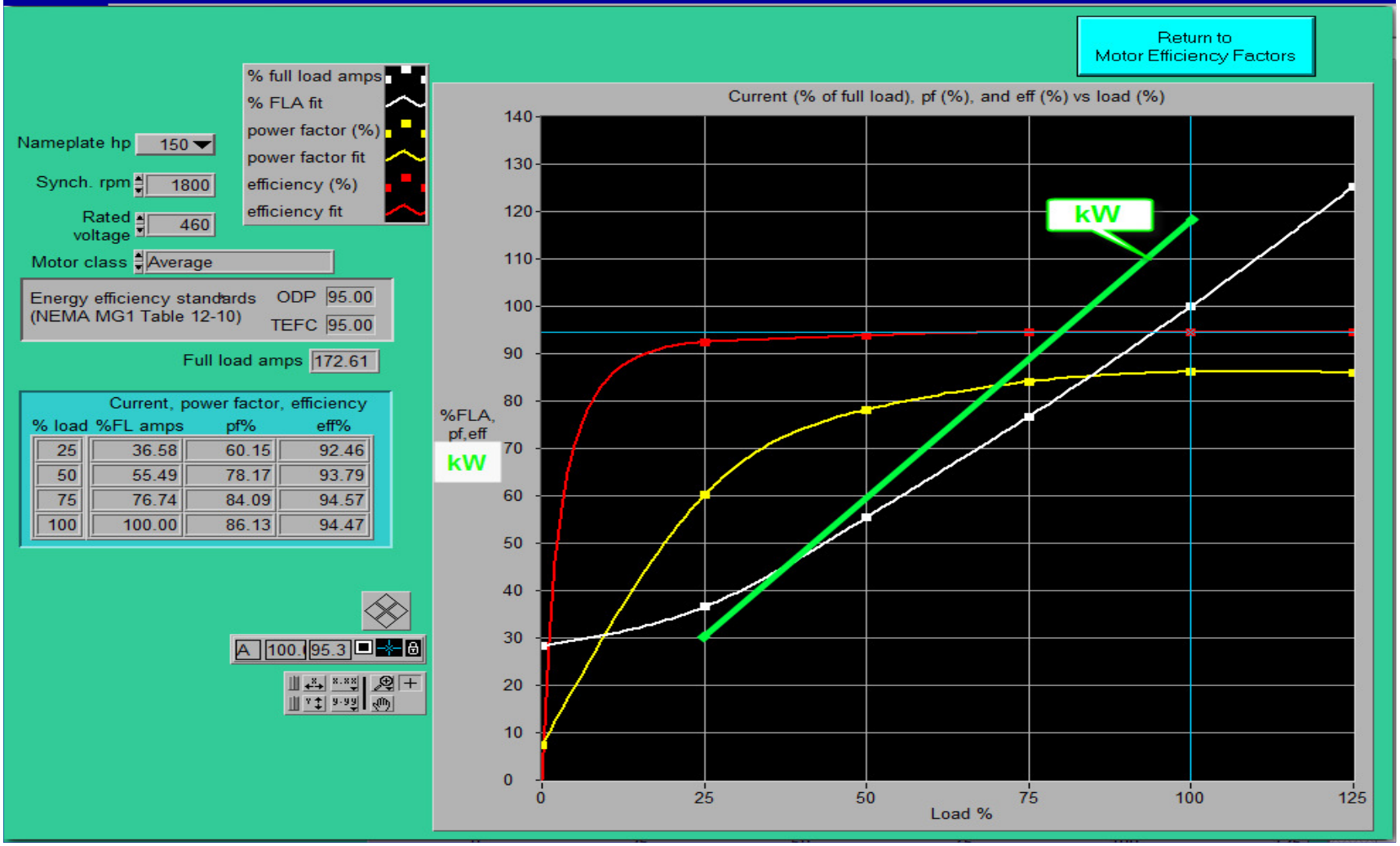


Courtesy: Toshiba

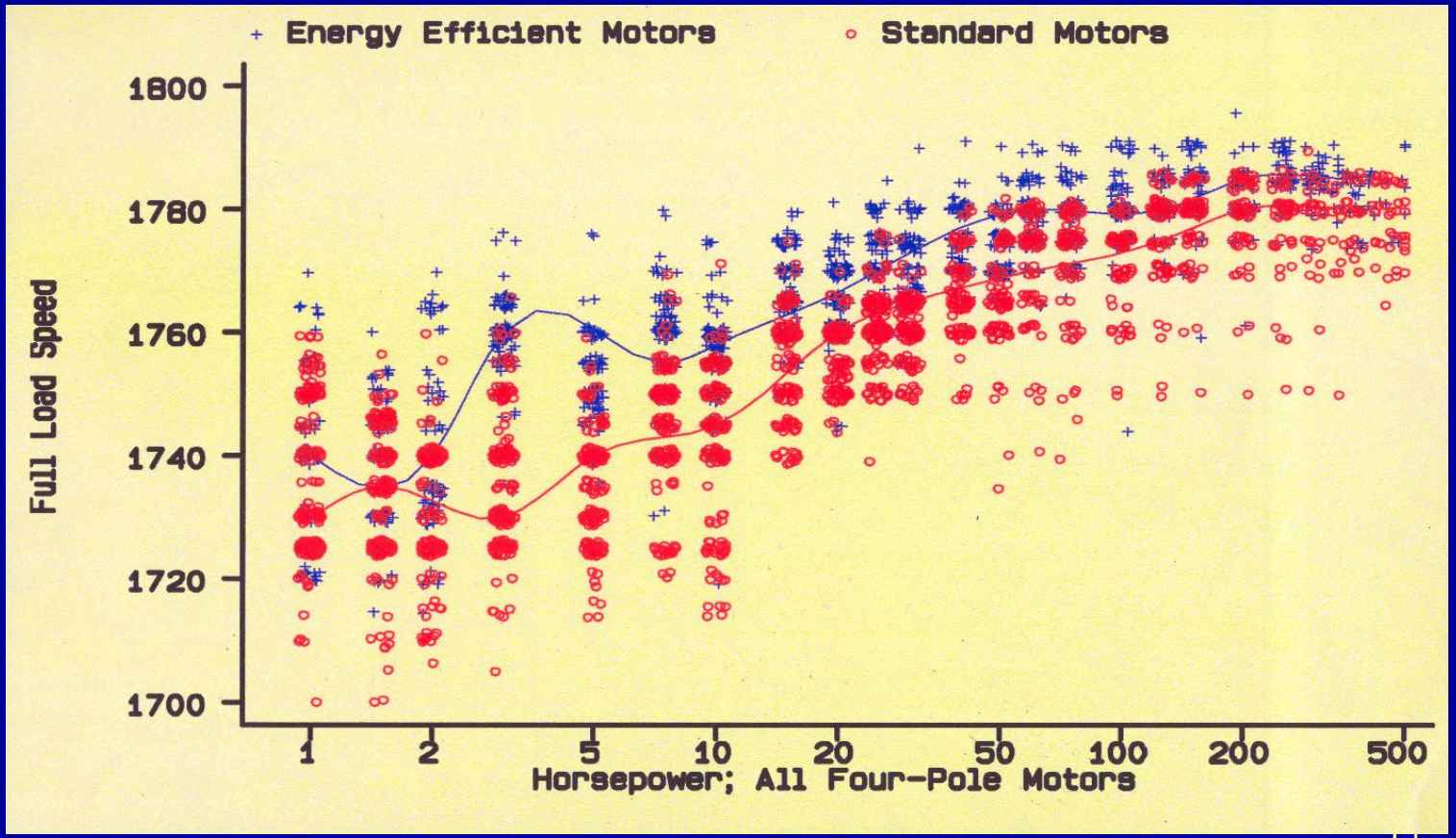
Replacement Results in Big Savings



Motor Part Load Performance



Efficiency versus full-load speed



Motor Management Planning-- Motor Survey and Screening Techniques

Motor Management Planning

Goals and Benefits:

- Provide dollar savings through reduced energy costs
- Minimize energy consumption (energy use per unit of product)
- Maximize efficiency while reducing downtime
- Improve system reliability and productivity

Rule of Thumb for Energy Management

One person-year of effort should be allocated for energy management activities for every $1 million spent on energy bills annually

After your program has been launched, the level can be set at one person-year for every $2-$5 million spent annually

Motor Management Program Building Blocks

- ❑ Accurate Motor Inventory Tracking System (or, conduct Motor Survey)
- ❑ New Motor Purchasing Policy: Specify Premium Efficiency
- ❑ Proactive Repair/Replace Policy
- ❑ Strategic Spares Inventory (PEM- Ready)
- ❑ Adopt Best Practices Repair Standards
- ❑ Predictive and Preventive Maintenance Planning

Information Requirements for Motor Management Planning

MotorMaster+ Inputs

- Understand Utility Rates
- Gather Motor Nameplate Data
- Establish Motor Operating Profiles
- Tune your Electrical Distribution System
- Obtain Measurements at Connected Loads
- Know Your Load Requirements

Key Energy Management Activities

Analysis

- Identify Energy Conservation Opportunities
- Evaluate Cost-effectiveness of Capital Improvements
- Prepare a Motor and Motor-Driven Systems Improvement Plan

MotorMaster+ Analysis Capabilities

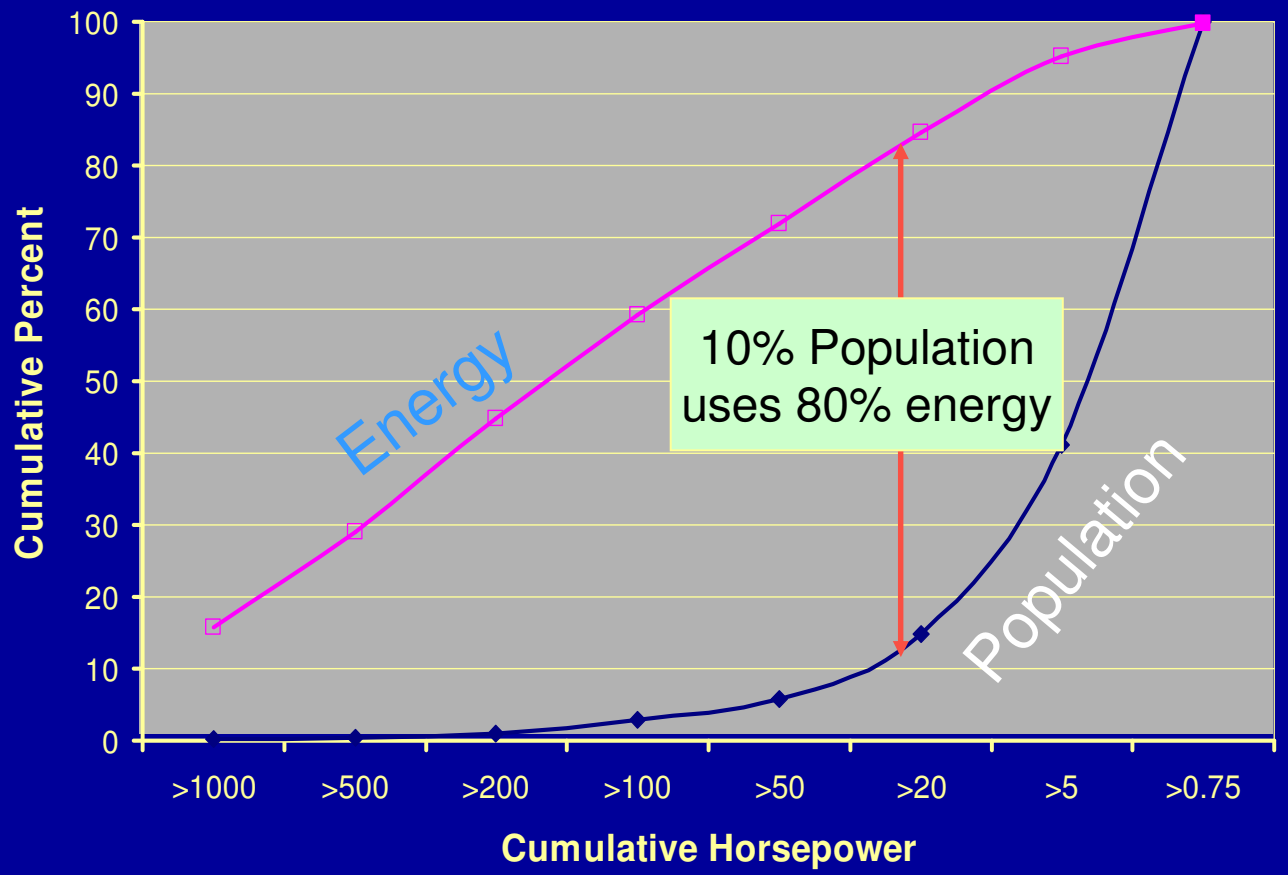
Implement Measurements and Verify Results

MotorMaster+ Savings Tracker

Specifying a Motor

- Horsepower rating (integral hp, 1-500)
- NEMA Design, Metric, Two-speed
- Enclosure type (ODP, TEFC, EXPL)
- Voltage rating
- Synchronous speed
- Special or Definite Purpose
- Frame Size
- Efficiency class

A small fraction of the motor population is responsible for most energy consumption



Note the descending order (left to right)

Additional Inventory Filters

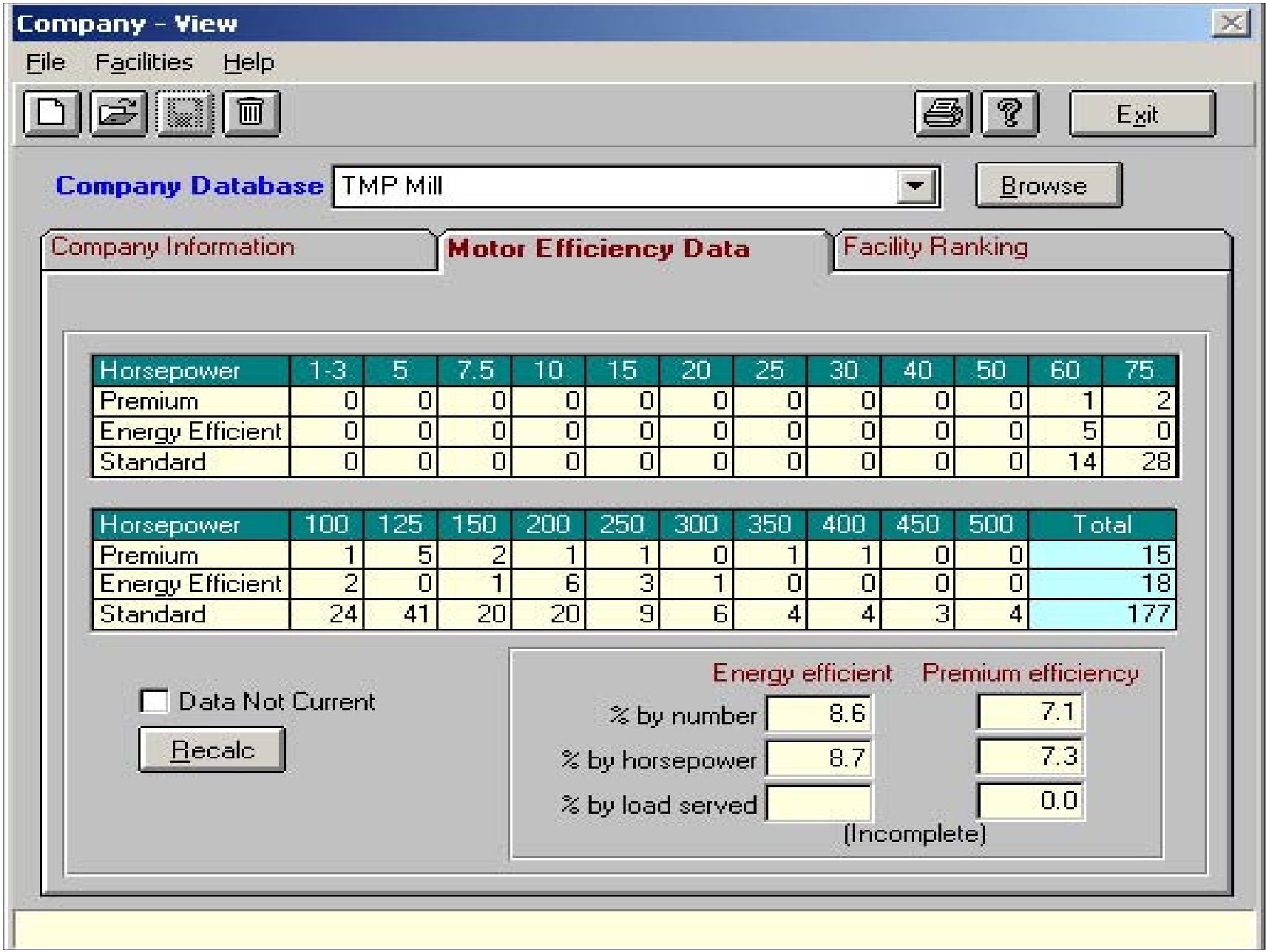
Focus On:

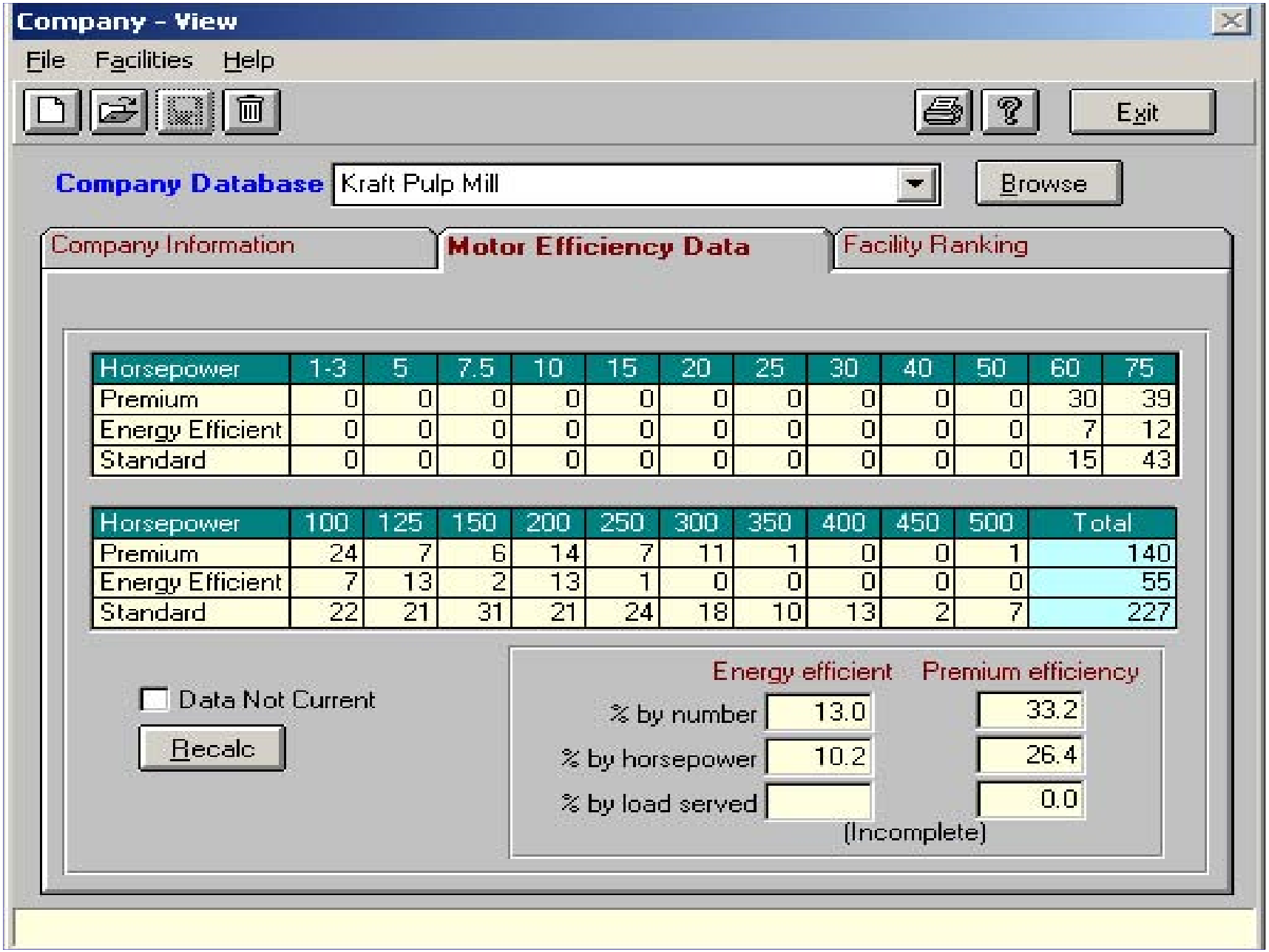
- **Non special or definite purpose motors**
- **Motors with accessible and readable nameplates**
- **Include spares**

Include information on the coupling, driven equipment, and load requirements

Motor Nameplate Information

- **Frame Type/Size**
- **Voltage**
- **Rated Horsepower**
- **Amps, Rated Load**
- Time Rating, i.e. Duty
- Maximum ambient Temperature
- **RPM at Rated Load**
- Insulation Class
- **Design Letter**
- Service Factor
- Frequency
- Number of Phases
- Locked Rotor Code, MG1 Part 10.37 (kVA/hp)
- **Efficiency, Rated Load**
- Other Optional Information

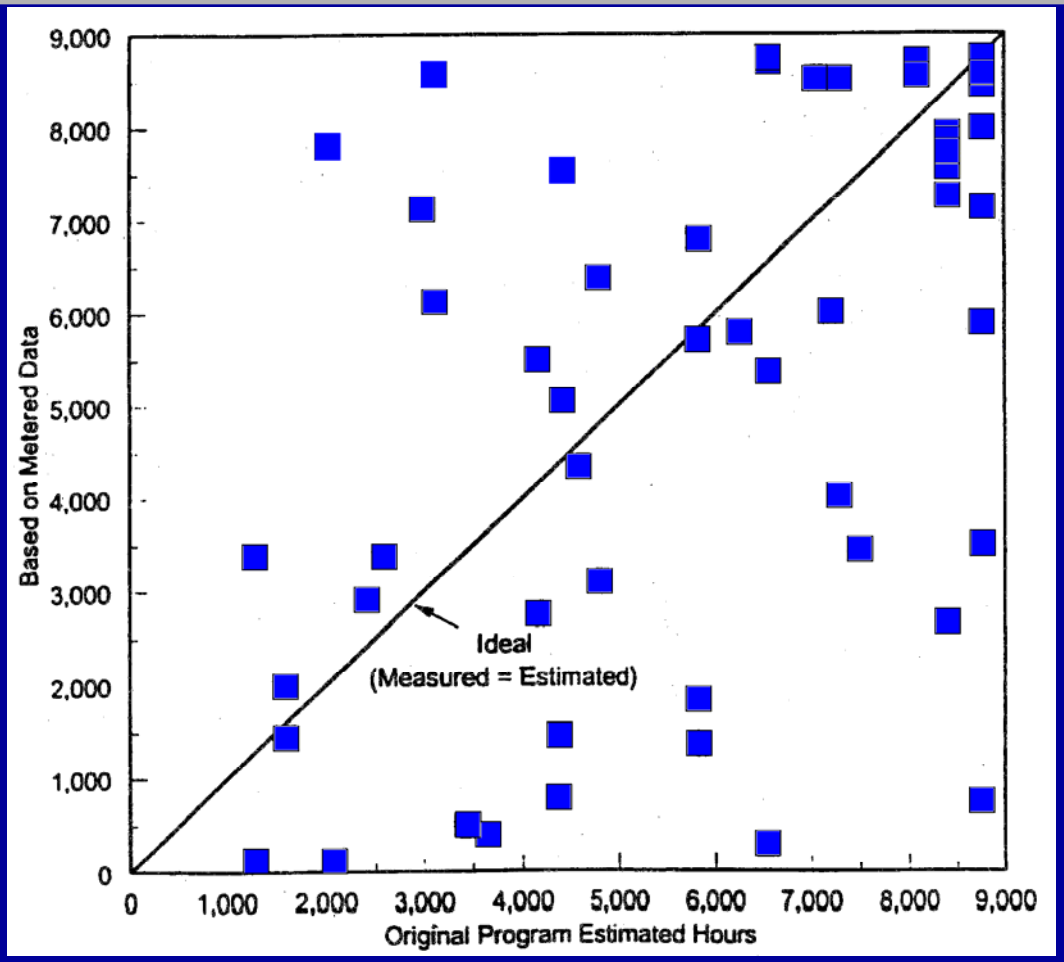

Company - View
File
Facilities
Help
Exit
Company Database
TMP Mill
Browse
Company Information
Motor Efficiency Data
Facility Ranking
Horsepower 1-3 5 7.5 10 15 20 25 30 40 50 60 75
Premium 0 0 0 0 0 0 0 0 0 0 1 2
Energy Efficient 0 0 0 0 0 0 0 0 0 0 5 0
Standard 0 0 0 0 0 0 0 0 0 0 14 28
Horsepower 100 125 150 200 250 300 350 400 450 500 Total
Premium 1 5 2 1 1 0 1 1 0 0 15
Energy Efficient 2 0 1 6 3 1 0 0 0 0 18
Standard 24 41 20 20 9 6 4 4 3 4 177
Data Not Current
Recalc
Energy efficient
Premium efficiency
% by number 8.6 7.1
% by horsepower 8.7 7.3
% by load served 0.0
(Incomplete)


Company - View
File
Facilities
Help
Exit
Company Database
Kraft Pulp Mill
Browse
Company Information
Motor Efficiency Data
Facility Ranking
Horsepower 1-3 5 7.5 10 15 20 25 30 40 50 60 75
Premium 0 0 0 0 0 0 0 0 0 0 30 39
Energy Efficient 0 0 0 0 0 0 0 0 0 0 7 12
Standard 0 0 0 0 0 0 0 0 0 0 15 43
Horsepower 100 125 150 200 250 300 350 400 450 500 Total
Premium 24 7 6 14 7 11 1 0 0 1 140
Energy Efficient 7 13 2 13 1 0 0 0 0 0 55
Standard 22 21 31 21 24 18 10 13 2 7 227
Data Not Current
Recalc
Energy efficient
Premium efficiency
% by number 13.0 33.2
% by horsepower 10.2 26.4
% by load served 0.0
(Incomplete)

Estimating Operating Hours

An evaluation of customer-supplied operating hour assumptions in PGE's Drive-Power program found widespread scatter. Measured or true values ranged from 0 to 8,000 hours for an assumed value of 2,000 hours; and from 500 to 8,760 hours for estimates of 6,500 hours

Operator Operating Hour Estimates



Motor Improvement Planning Action Items

- Replace critical motors with histories of frequent failures immediately
- Develop a new motor purchase policy
- Determine which operable motors should be immediately replaced based on cost-effectiveness criteria
- Identify which motors should be replaced with Premium Efficiency units when they fail
- Establish a PEM-Ready spares inventory

Forget First Cost!

100 HP TEFC EPACT motor costs ~ $6,256

It costs $38,985 to operate per year!

(or 623% of first cost)

@ $.054/kWh & $4.87/kW, 8150 hrs/yr, 100% load

Now consider a car: First cost ~ $25,000

Even at $3.00/gal, annual fuel costs are only about $1,500 or 6% of first costs

@ 12,500 miles/year, 25 mpg

Equivalent Rates of Use

If the new car used energy at the same ratio of first cost to annual operating cost as the motor:

---It would have to be driven about 216,375 miles or 348,220 km every two months, or

---Gasoline would have to be priced at $311.58/gal (or $82.30/liter)

Annual Savings from Specifying New *NEMA Premium™* Efficiency Motors

	Full-load Motor Efficiency (%)		Annual Savings from Use of a NEMA Premium™ Efficiency Motor	
Horsepower	Energy Efficient Motor	NEMA Premium™ Efficiency Motor	Annual Energy Savings, kWh/year	Annual Dollar Savings, $/year
10	89.5	91.7	1,200	**$60**
25	92.4	93.6	1,550	**80**
50	93.0	94.5	3,820	**190**
100	94.5	95.4	4,470	**225**
200	95.0	96.2	11,755	**590**

Note: Based on purchase of an 1,800 RPM, Totally Enclosed Fan-Cooled motor with 8,000 hours per year of operation, 75% load, and an electrical rate of $0.05/kWh.

Contingency planning - making the change when a failure occurs

The alternatives evaluation picture changes dramatically when failures occur

Changes that couldn't be justified when the system was functional may very well be after failure

The alternative may actually be less costly than simple repair/replacement of the existing component

Turn Misfortune to Advantage

A motor failure can provide a good opportunity to tune up other aspects of the system:

Downsize motor where appropriate.

- Evaluate driven load speed with respect to new motor; change sheaves size if warranted. Remember pump and fan drive power can vary at the cube of speed or even greater.
- Consider upgrade to an ASD and inverter duty motor.

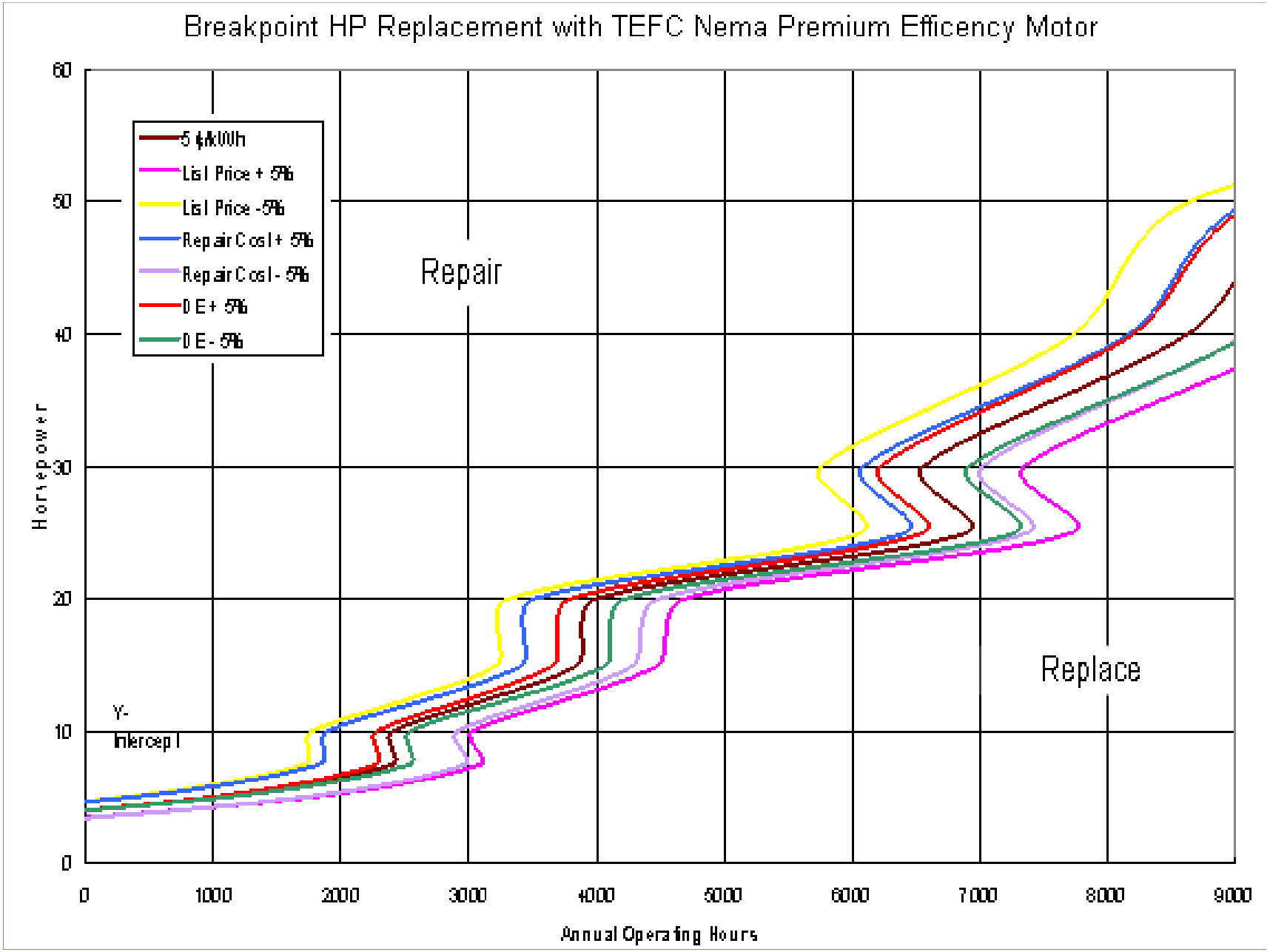
Repair versus Replace: You Need to Consider...

- First cost of repair and new purchase.
- Efficiency of existing and proposed new motor.
- Urgency and availability of each alternative.
- Possible modifications to the mounting.
- Annual hours of operation.
- Cost of down time and repairs from a possible early failure in either scenario.
- Utility incentives

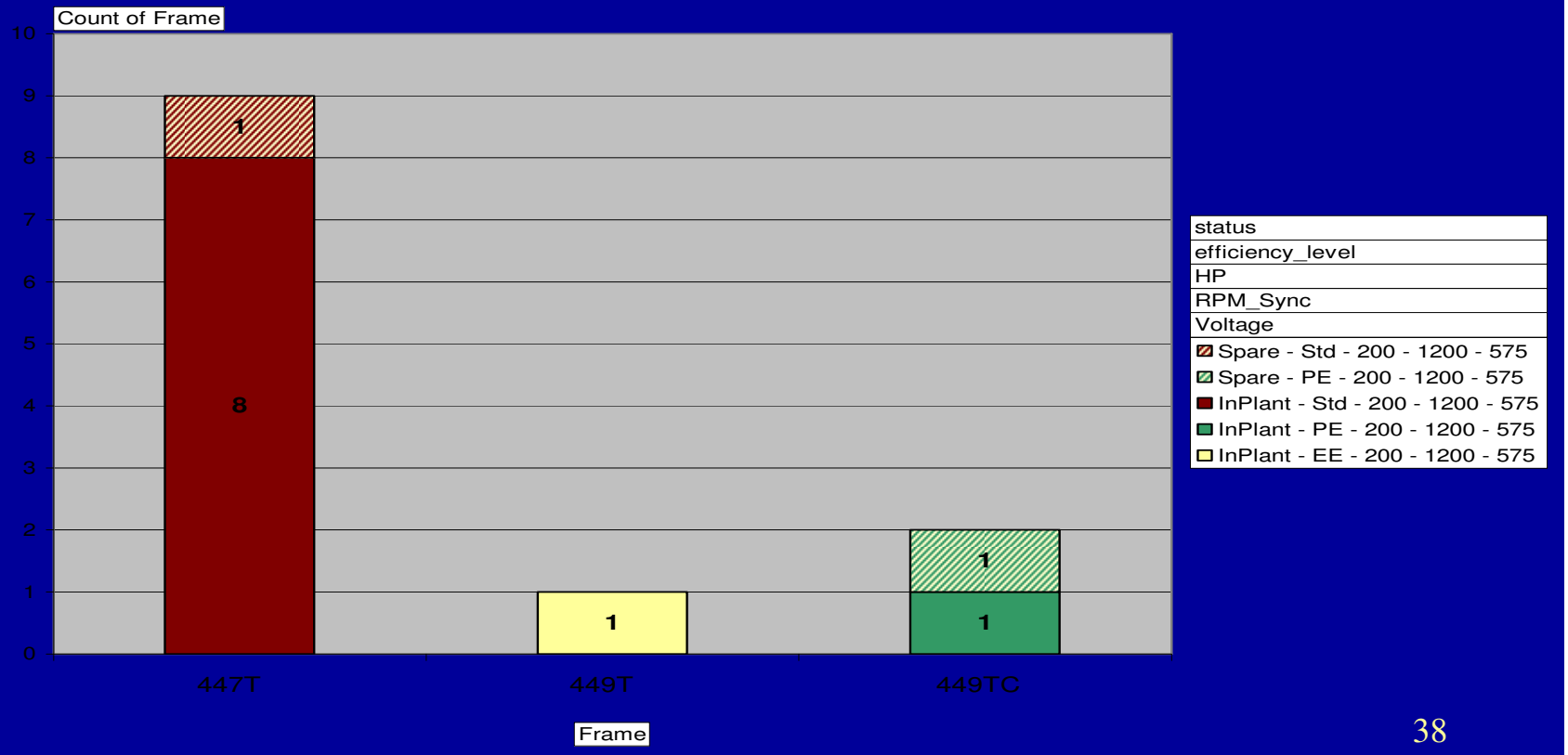
Replace versus Repair Existing Standard Efficiency Motors

	Motor efficiency (%)		Annual Savings from Use of a NEMA Premium™ Efficiency Motor	
Horsepower	Standard Efficiency Motor	NEMA Premium™ Efficiency Motor	Annual Energy Savings, kWh/year	Annual Dollar Savings, $/year
10	85.7	91.7	3,445	**$170**
25	88.9	93.6	6,305	**315**
50	91.1	94.5	8,725	**435**
100	91.7	95.4	18,820	**940**
200	92.8	96.2	34,910	**1,745**

Note: Based on purchase of an 1,800 RPM, Totally Enclosed Fan-Cooled motor with 8,000 hours per year of operation, 75% load, and an electrical rate of $0.05/kWh.

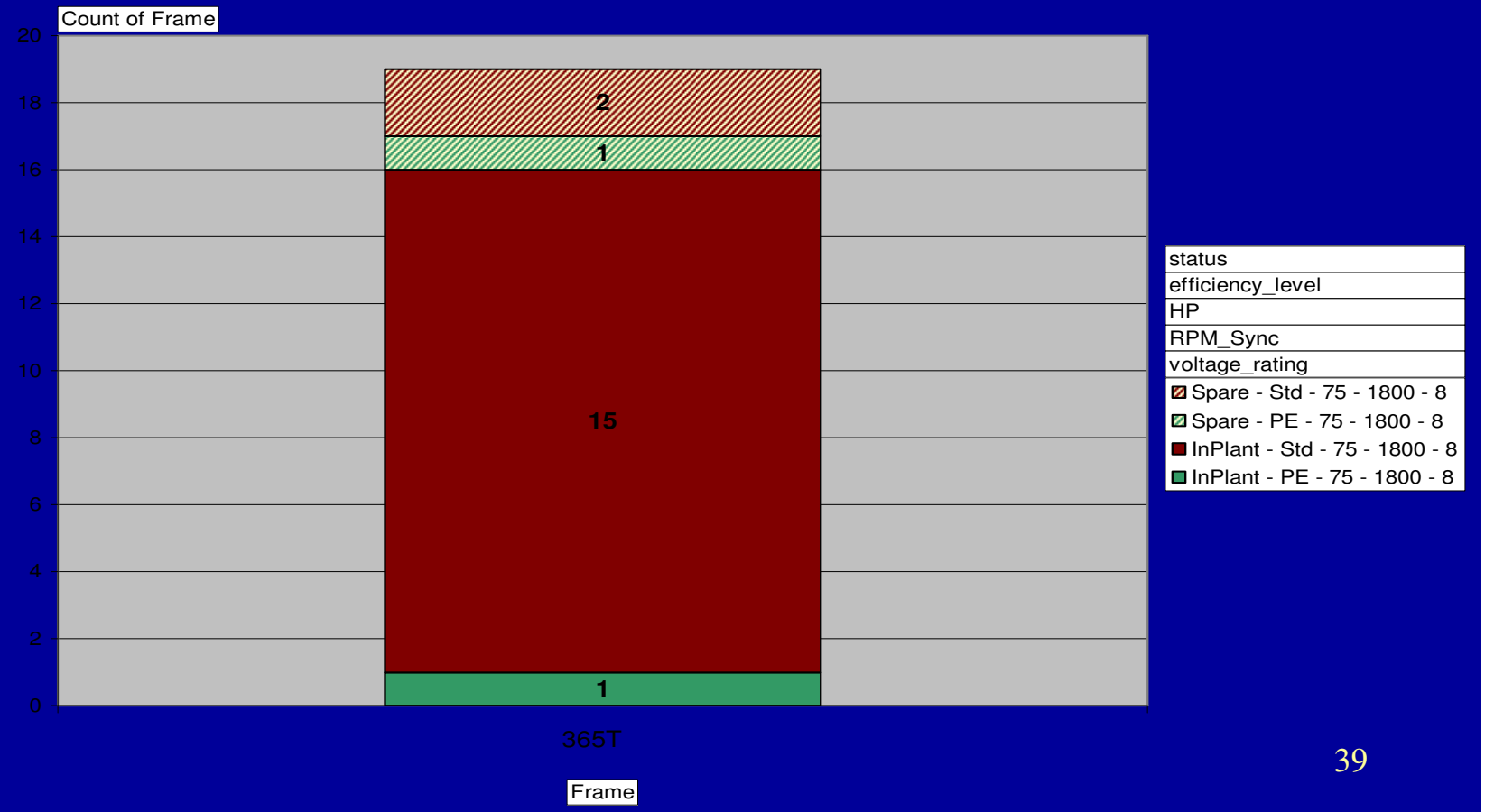

Breakpoint HP Replacement with TEFC Nema Premium Efficency Motor
Horsepower
Annual Operating Hours
0
10
20
30
40
50
60
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
$ /kWh
List Price + 5%
List Price -5%
Repair Cost + 5%
Repair Cost - 5%
EE + 5%
EE - 5%
Repair
Replace
Y-Intercept

Coverage Charts tell a Story
(for 200 hp 1200 RPM Motors)

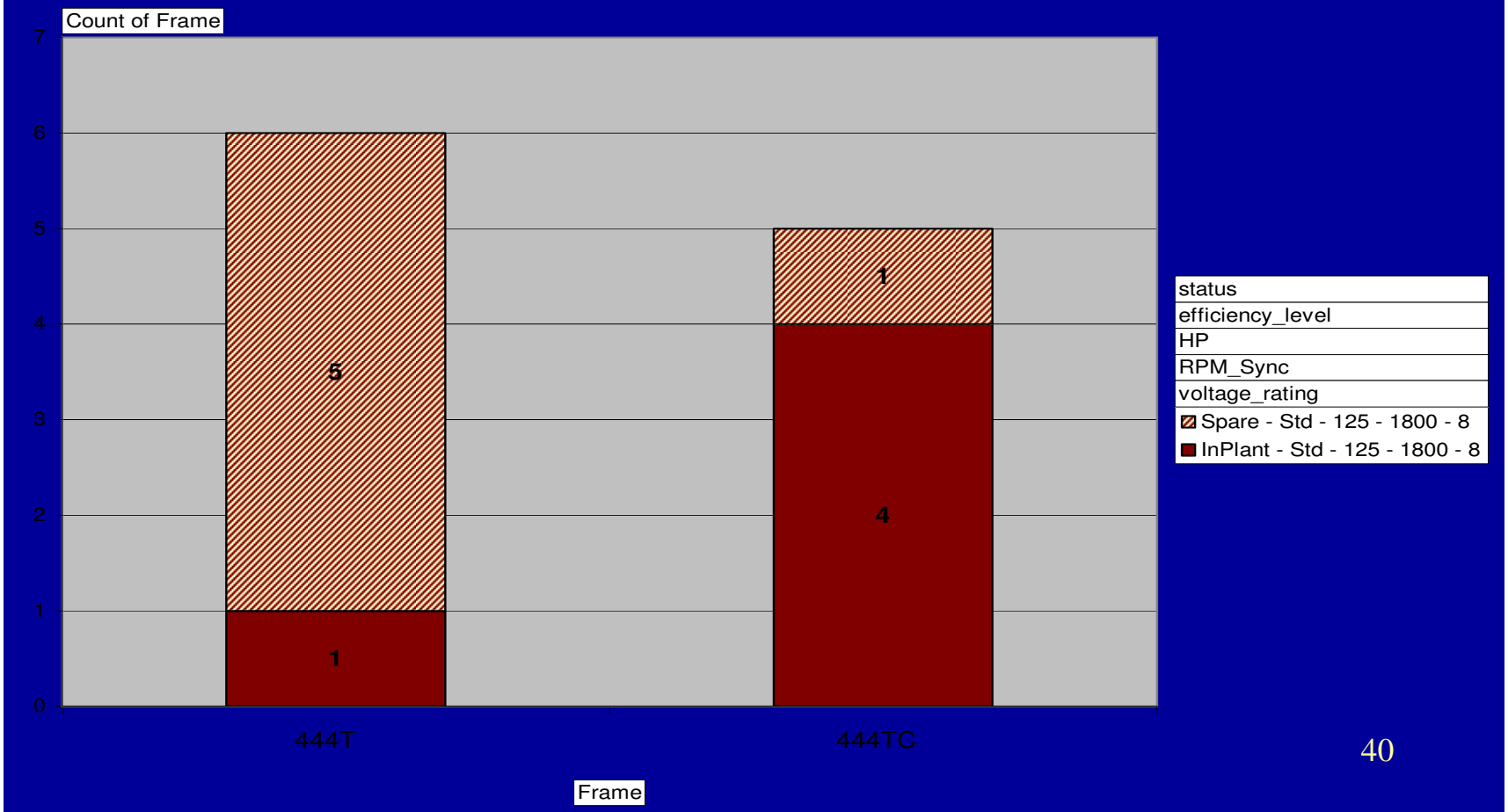


A Strategic Spares Inventory

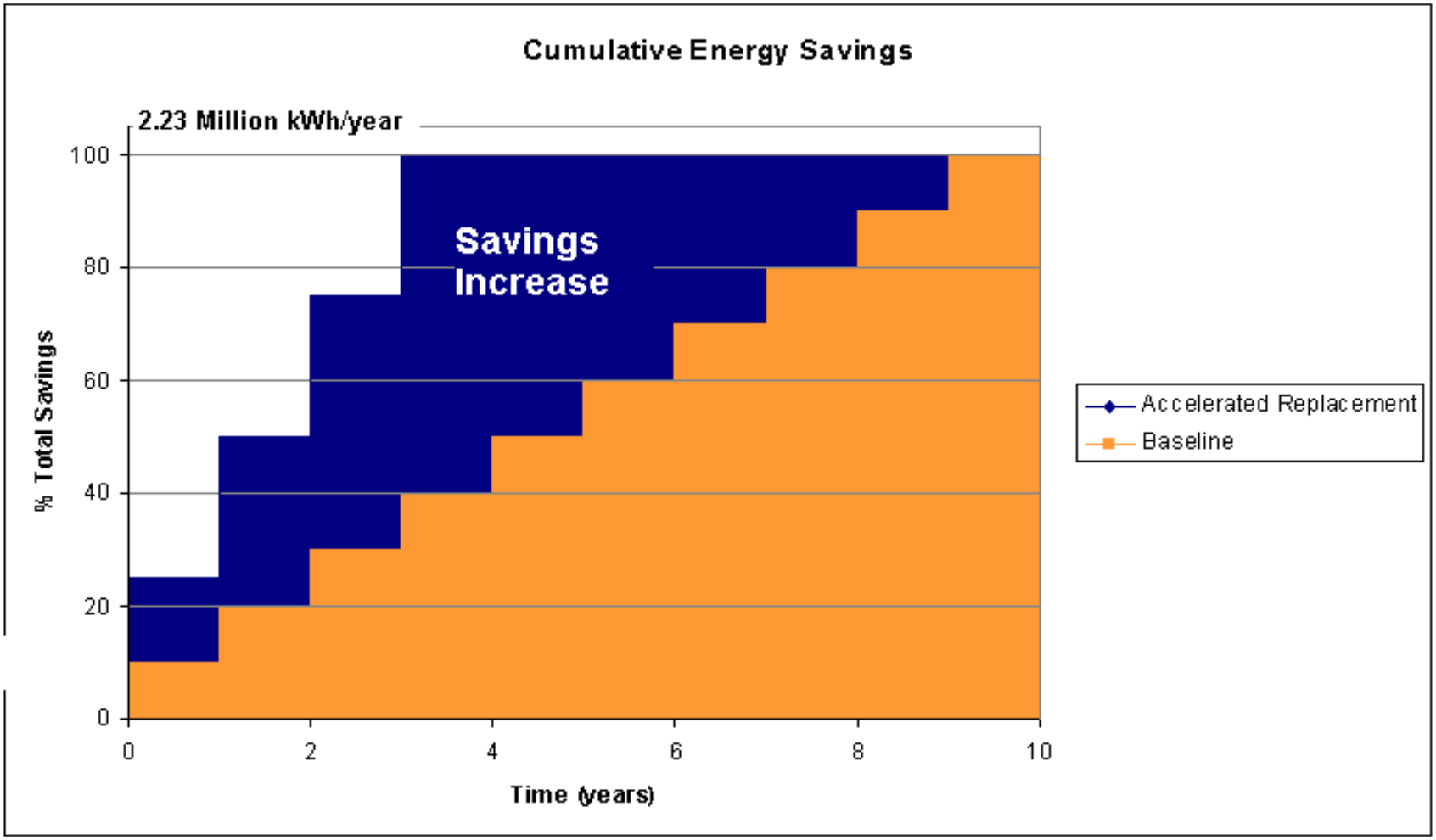
(for 75 hp 1800 RPM Motors)



Excess Number of Spares?
(125 hp 1800 RPM)



Accelerated Motor Replacement



Motor Improvement Plan

Old Motor	New Motor
Motor # 1	Replace W / EE When Failed
Motor # 2	Downsize / Replace W / EE When Failed
Motor # 3	Immediate Replacement W / EE
Motor # 4	Replace W/Standard or Repair When Failed
Motor # 5	Investigate ASD Potential

MotorMaster +

Summary

- Motor nameplate
- Type of load
- Operating hours
- Field data
  (Amps, Volts, Watts, PF, RPM)
- Utility rates
- Utility rebates
- Repair or replace?
- Savings Tracking
- Batch Analysis

Motor Energy Management Plan


MotorMaster for General Distribution, Inc.
Field data
List
Compare
Savings Tracker
Options
Help
Company
Utilities
Facilities
Departments
Processes
Inventory
MotorMaster+4.0
EXIT
Batch Analysis
List
Compare
Life Cycle
Savings Tracker
Billing
Production
Reports
Version 4.00.00 (01/01/2003)
90% free
Wed, Mar 12, 2003 4:19 pm

What is MotorMaster+?
Decision Support Software

- Motor Price and Performance Database
- Motor Selection Tool
- Energy Savings Analysis
- Inventory Management
- Maintenance Logs
- Energy Management
- Energy Accounting
- Utility Motor Rebate Support
- Life Cycle Costing
- Tracks Energy Savings and Emissions Reductions

Motor Manufacturers' Price and Performance Database

- Electronic catalog with data for over 27,000 motors
- NEMA A-D, IEC (Metric), Two-Speed
- General and Definite Purpose (U-Frame, IEEE 841, Washdown, Severe-Duty, Inverter-Duty, Close-Coupled Pump)
- Updated approximately every two years

Inventory Management Capabilities

Motor Inventory

Query

Location Searches

List: All Motors in descending order of hp or annual energy consumption.

- **All Motor**
- **By Facility**
- **By Department**
- **By Process**
- **By Serving Utility**

Descriptor Searches/ Selective Reports

- Motors with power supply problem (phase unbalance >=3%, 2%, 1%, etc..
- Indicate all motors with power factor <=stated value
- Identify rewound motors
- List Motors >=specified age
- List motors by process equipment type
- Identify motors >=or <= stated hp value
- List all spares
- List all oversized motors (load <=40%, 50%)
- Show motors with annual energy use > stated value.

Inventory Management

- Track spare and in-service motors.
- Store nameplate, operating profile, field measurement, and load-related information.
- Automatic motor load and efficiency estimation features.
- Can copy catalog or inventory motors.
- Possible to import existing motor databases into the Inventory module.

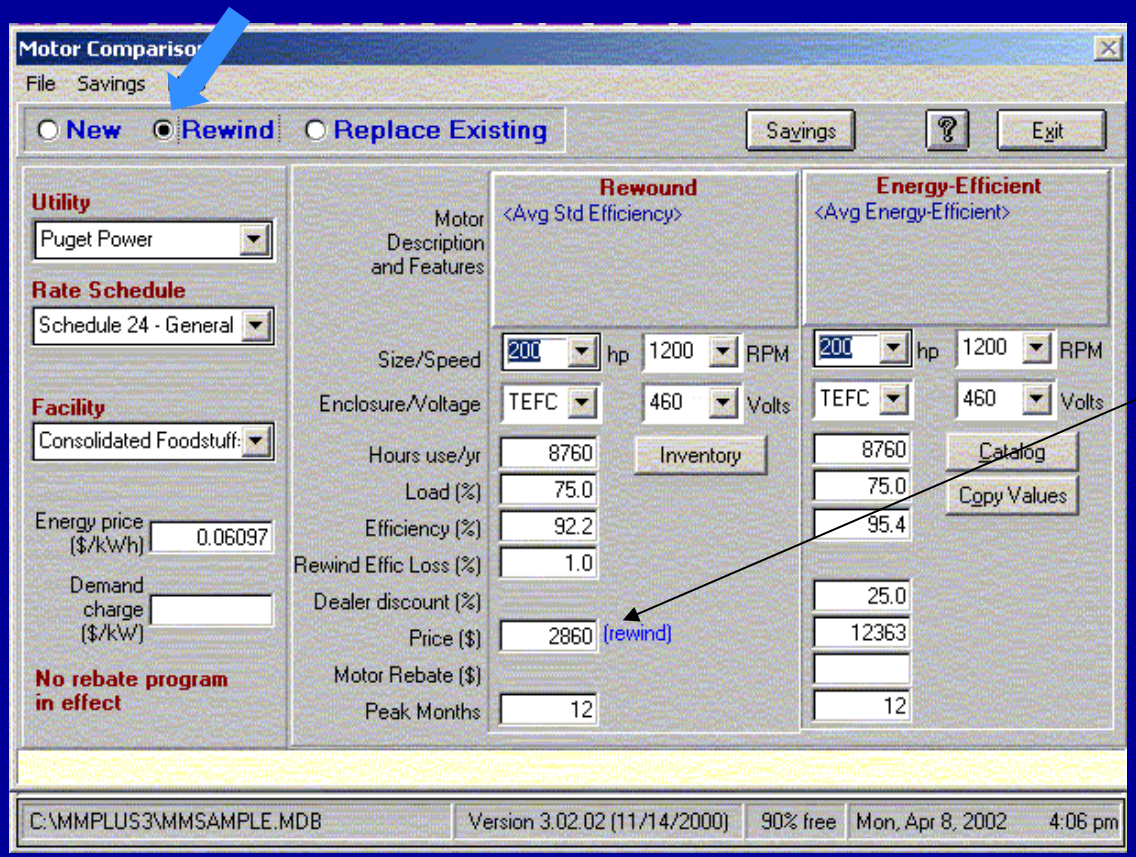
Motor Efficiency Determination

Laboratory: IEEE 112B Basis for NEMA Nominal Efficiency; Nameplate per MG1 Table 12-10

MotorMaster+ Methods

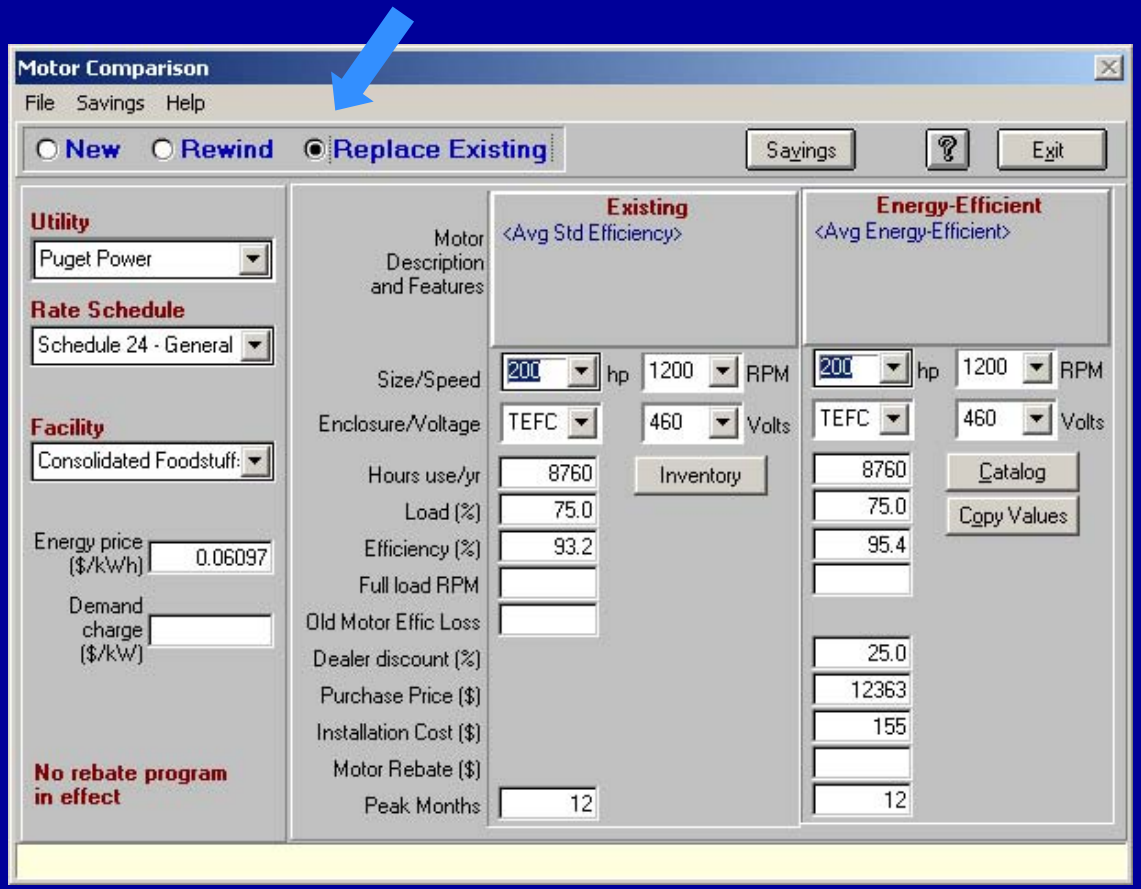
- **ORMEL96 - Calculates Part Load Efficiency from Measured Slip plus Nameplate Data**
- **kW - Calculates Load; Looks up Part-load Efficiency**
- **Slip - Calculates Load; Looks up Part-load Efficiency**
- **Amp - Calculates Load; Looks up Part-load Efficiency**

Failed Motor Efficiency Upgrade

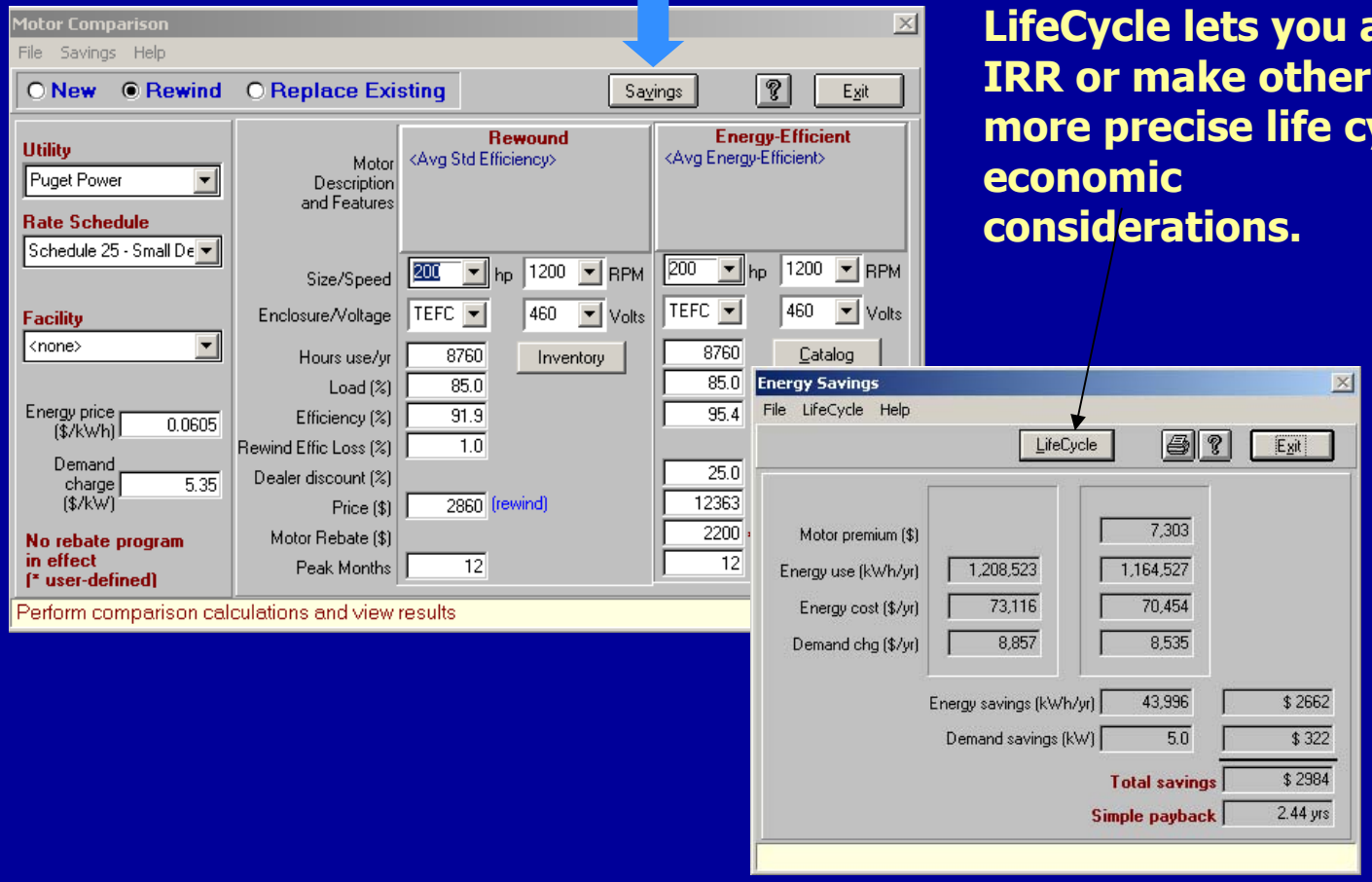


From user-editable default table.

Functional Motor Efficiency Upgrade



Consider discounts, rebates, and other economic factors



LifeCycle lets you apply IRR or make other more precise life cycle economic considerations.

Adding Utility Rate Schedules

Can accommodate two seasons (generally Summer and Winter)

Enter demand charges ($/kW-mo) for each season

Enter energy charges for each season.

Can handle up to three energy charge “tailblocks”.

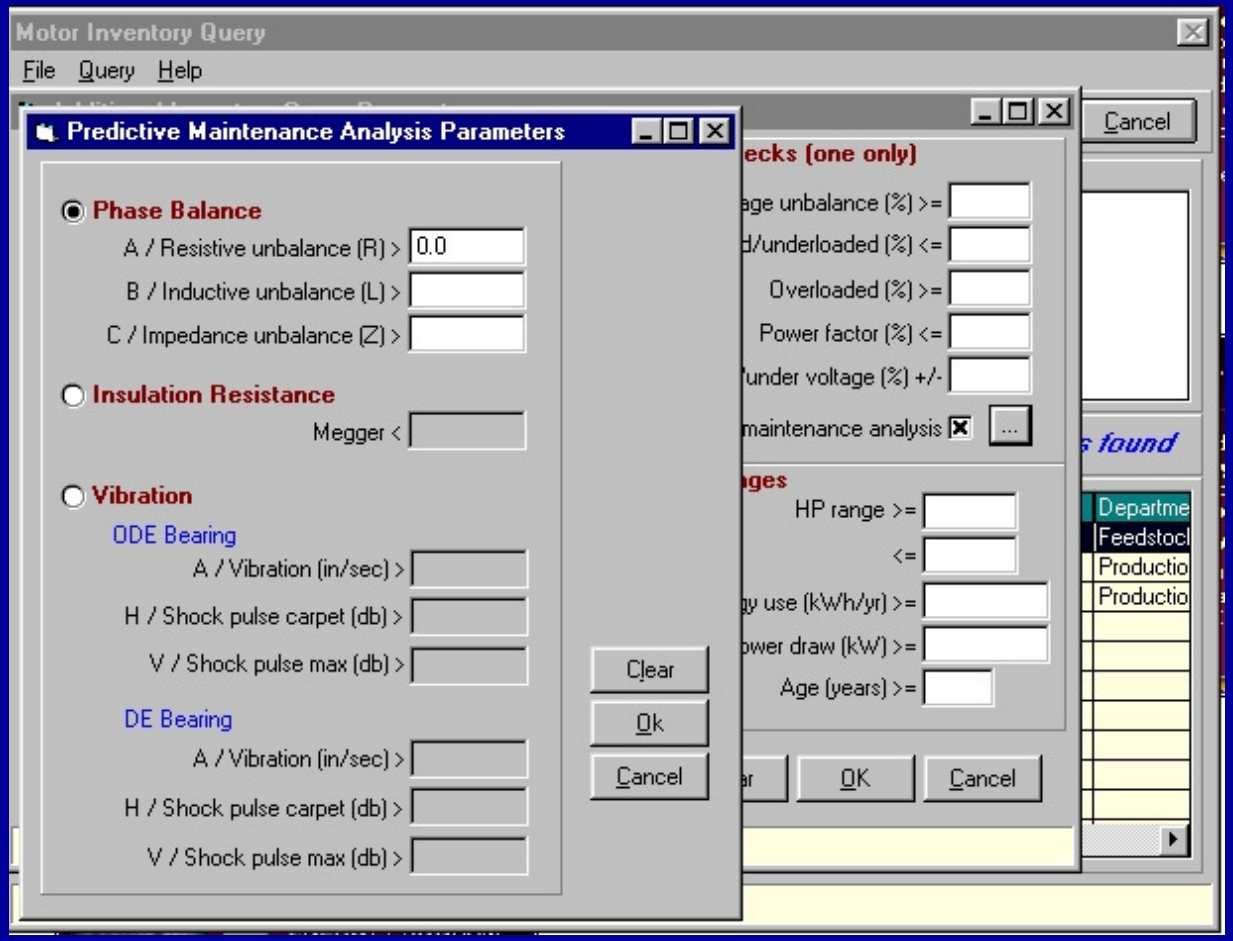
Enter any number of utilities and rate schedules.

Assign at Facility Level.

Life Cycle Cost Analysis

- Computes the after-tax return-on-investment in an energy efficiency measure.
- Displays cash flows, net present value, and the benefit-to-cost ratio.
- Linked to Compare and Batch Analysis modules.

Maintenance Logs



Savings Tracker

Uses “before” and “after” measured values to validate energy and dollar savings from conservation and efficiency improvements.

Motor and driven-equipment Energy Action records are aggregated with total savings indicated.

May create a Greenhouse Gas Emissions Reduction report (EIA 1605 EZ).

Energy Management using Batch Analysis

- Use Batch Analysis to determine which in-plant motors are candidates for immediate replacement with a new Premium Efficiency motor.
- Identify which motors should be replaced at their time of failure.
- Know which motors should be repaired and returned to service when they fail.

Batch Analysis Capability

Replacing Groups of Inefficient Motors

- MotorMaster+'s Batch Analysis can accept inputs from the Inventory module, automatically conduct analyses, and then summarizes dollar and energy savings due to changing out all motors (in a given plant, department, etc.) or only those motors with simple paybacks below a target value.

Batch Analysis Choices

Motor Changeout Choices. The analyst can replace existing motors with a particular brand of motor or identify the "best available" replacement motor. This motor yields the most rapid simple payback on investment.

Batch Upgrade Capability. This feature allows the user to specify only severe-duty, NEMA Premium or IEEE 841 replacement motors.

Optimization and Auto Sizing Routine

Identify the "best available" motor. The MotorMaster+ batch analysis will select the "best" replacement motor based on:

- full and part-load efficiency values (bin)
- discounted list price
- centrifugal load speed/slip relationships.

The package of "best" replacement motors provides the quickest overall payback on investment.

Underloaded Motors

Consideration of Oversized and Underloaded Motors. A motor is considered oversized if it constantly operates at less than 40% of full load. Compares' Auto Downsizing analysis will automatically consider replacement motors of the same size as well as smaller motors.

MotorMaster+ will not allow loads on potential replacement motors to exceed 85%.

How to obtain MotorMaster+

Download from the

U.S. Dept. of Energy's ITP website at:

http://www1.eere.energy.gov/industry/bestpractices/software.html#mm

Additional industrial efficiency resources are available at:

http://www1.eere.energy.gov/industry/