API 541 5th Edition – Understanding the Changes and Updates to one of the Petroleum Industry's Premier Specifications

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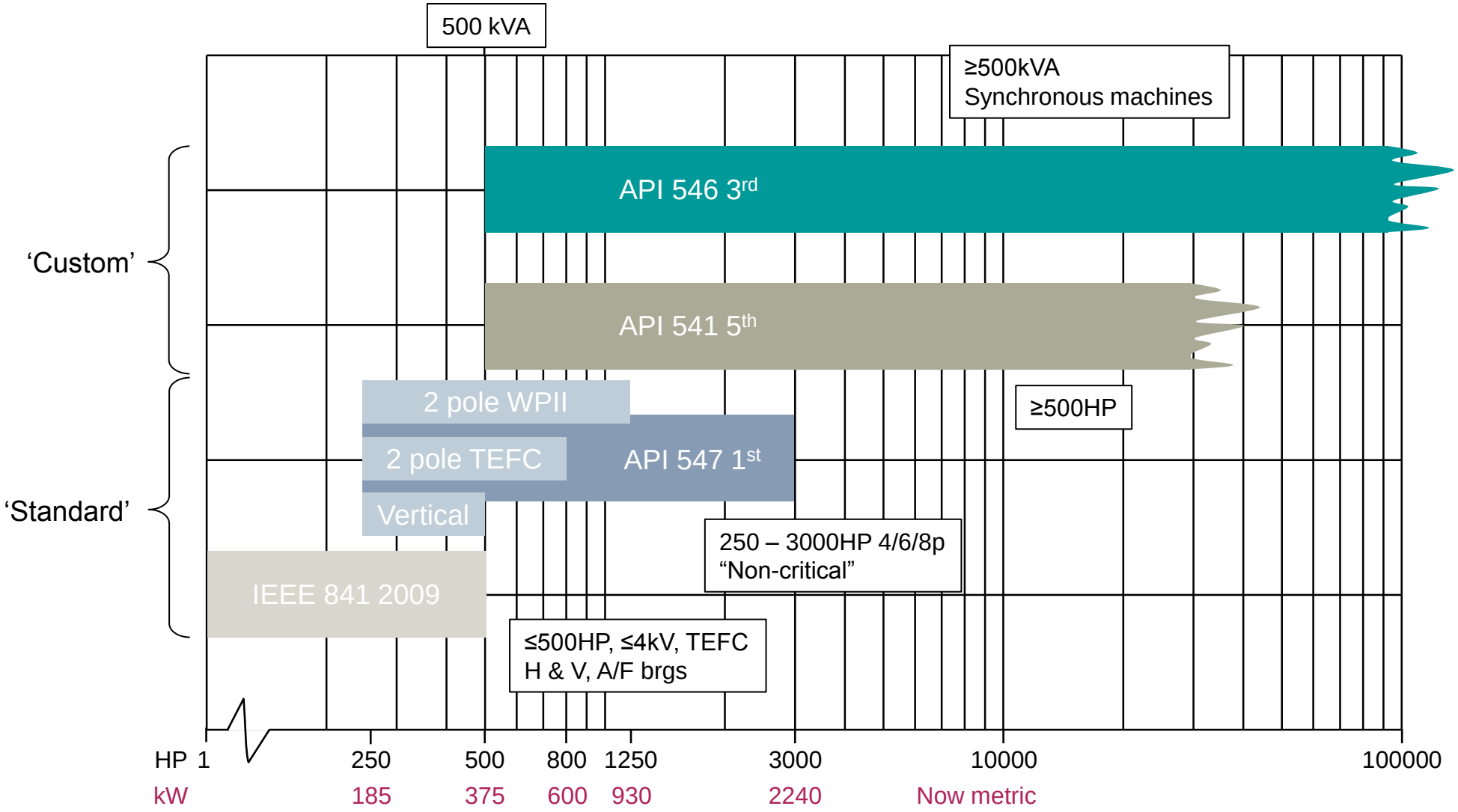
Petroleum Industry Motor Standards



American Petroleum Institute – 541 History

- **RP 541 introduced in 1972**
- **541 2nd Edition introduced in 1987**
- **541 3rd Edition introduced in 1995**
- **541 4th Edition released June 2004**
- **541 5th Edition – Released December 2014**

➢ **End User Driven Specification, with representation by Motor Suppliers.**

API 541 5th - Timing / Process of Revision

- Working group assembled April 2008
  - End users, Consultants . . . and motor OEMs
- Open discussions on suggested improvements
  - Incorporate API 546 revisions as appropriate
  - Sub-groups to discuss/recommend broader changes
- Ballot (second) approval May 2011
- Print proof reviewed in July 2012
- Published December 2014

Why Use API 541?

- Standard specification that provides customized product
  - Creates motor definition
  - Dictates proposal preparation
  - Simplifies proposal evaluation
  - Provides for a reliable machine
- Utilizes comprehensive data sheets
  - Important to *everyone* involved from manufacturer to user

API 541 5th Edition - Scope

This standard covers the minimum requirements for special purpose form-wound squirrel-cage induction motors 375 kW (500 Horsepower) and larger for use in petroleum, chemical and other industry applications.

Note 1: Special purpose machines typically have one or more of the following characteristics:

1. Is in an application for which the equipment is designed for uninterrupted, continuous operation in critical service, and for which there is usually no installed spare equipment.

2. Is larger than 2250 kW (3000 hp) for speeds 1800 RPM and below.

3. Is rated 600 kW (800 hp) or greater for two-pole (3000 or 3600-RPM) machines of totally-enclosed construction, or rated 930 kW (1250 hp) or greater for two-pole machines of open or guarded construction (including machines with WP-I or WP-II type enclosures).

4. Drives a high-inertia load (in excess of the load WK2 listed in NEMA MG 1 Part 20).

5. Uses an adjustable speed drive as a source of power.

6. Is an induction generator.

7. Is a vertical machine rated 375 kW (500 hp) or greater.

8. Operates in abnormally hostile environments..

Baseline…..
API 541 4th Edition –Standard Motor Features – Basic Design

- Class B temperature rise at 1.0 SF by RTD (2.3.1)

HP	Voltage	Method of Determination	Class A	B	F	H
HP < ∞	V < ∞	RESistance	60	**80**	105	125
HP ≤ 1500	V < ∞	DETector	70	**90**	115	140
HP > 1500	V ≤ 7000	DETector	65	85	110	135
HP > 1500	V > 7000	DETector	60	80	105	125

- Maximum sound pressure level = 85 dB(A) @ 3 feet (2.1.3)

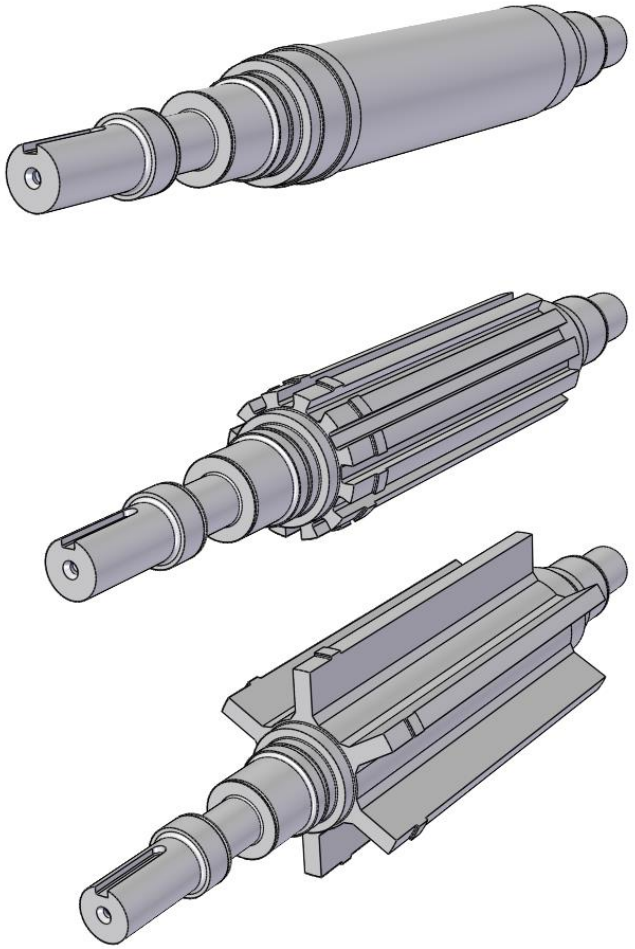
- Suitable for 80% voltage starting
- Special starting duty: 2 Hot / 3 Cold Starts, Minimum Safe Stall Time criteria: the greater of 150%, or 5 sec more than acceleration time.
- Inrush current <= 650% of full-load current

- C-5 stator lamination core plate
- Both ends of each stator-phase winding brought out to main box (1000 hp & +)

Baseline…..
API 541 4th Edition –Standard Motor Features – Basic Design

- Metal fan-covers
- WPII - stainless steel filters & provisions for differential pressure switch
- Stainless steel hardware (up to ½“)
- Specific mounting surface dimension tolerances

- Heat-treated forged shafts (A4000 Series) for:
  - Motors with finished shaft diameter >=8 inches
  - 2-pole motors >= 1000 hp
  - Motor operating above first critical speed
  - Reciprocating loads and motors using tapered hydraulic-fit couplings



API 541 4th Edition –Standard Motor Features

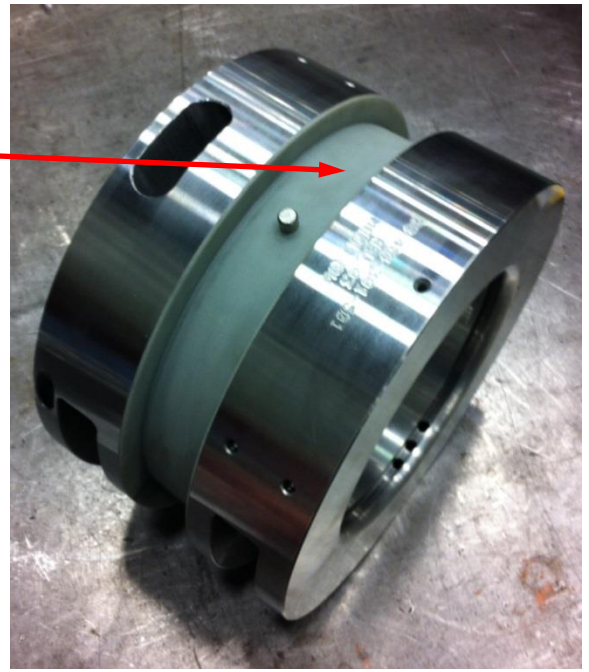
- Specific TEWAC and Vertical Motor design criteria.

- Split-sleeve, ring-oil lubricated bearings (horizontal units)
  - Bearing temperatures not to exceed 93ºC at rated output
  - Provisions for shaft displacement probes (motors operating >= 1200 rpm)

- Both bearings insulated

- 3-Wire, 100 Ohm Stator RTD's (2/Phase)
- Flanged Forced/Flood Lube Provisions (when applicable)

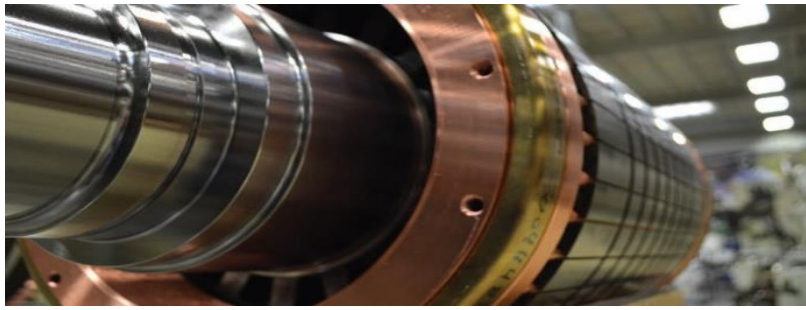
- Shaft material certificate
- Foundation loading data on GA drawing



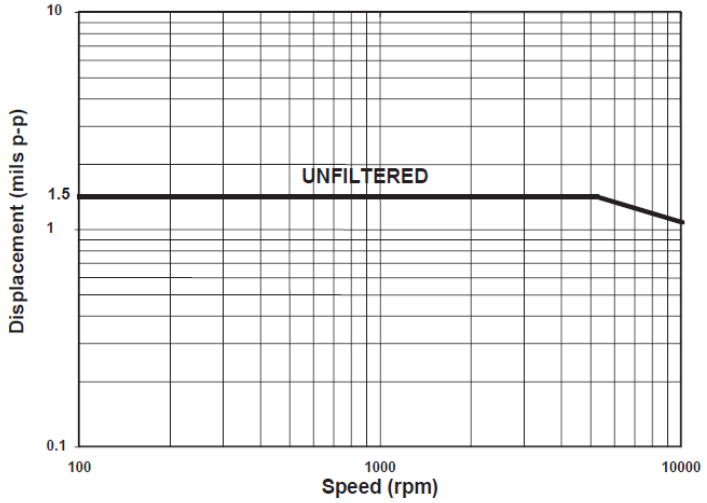
Sleeve Bearing w/ Insulation

API 541 4th Edition –Standard Motor Features

- **Copper rotors** (Aluminum allowable if approved by purchaser) with Phosphorous-free braze material (Cu bar rotors)
- Special rotor balance procedures (Step Balance 2 & 4-poles)



- 1.5 mils (0.0015”) p-p shaft displacement vibration limit (unfiltered)
- 0.1 IPS (inches/sec) vibration limit on bearing housing
- 0.6 mil (max), cold-to-hot magnitude resultant vector change (1x) vibration criteria (4.3.3.11).



Notes:
1. The unfiltered vibration limits for machines up to 5000 rpm rated speed shall not exceed 1.5 mils p-p displacement. For machines with rated speeds in excess of 5000 rpm, the unfiltered vibration limit shall not exceed sqrt (12000/*N*) where *N* is the maximum rated continuous speed.
2. Vibration displacement at any filtered frequency below running-speed frequency shall not exceed 0.1 mil or 20% of the measured unfiltered vibration displacement, whichever is greater.
3. Vibration displacement at any filtered frequency above running-speed frequency shall not exceed 0.5 mil peak-to-peak.
4. Vibration displacement filtered at running speed frequency (runout compensated) shall not exceed 80% of the unfiltered limit.

Figure 1—Shaft Vibration Limits (Relative to Bearing Housing Using Non-contact Vibration Probes): for All Hydrodynamic Sleeve Bearing Machines; with the Machine Securely Fastened to a Massive Foundation

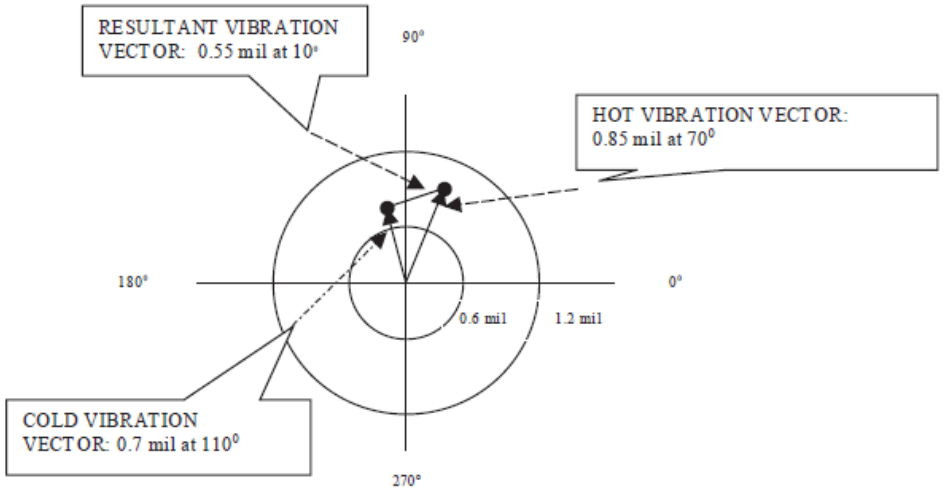
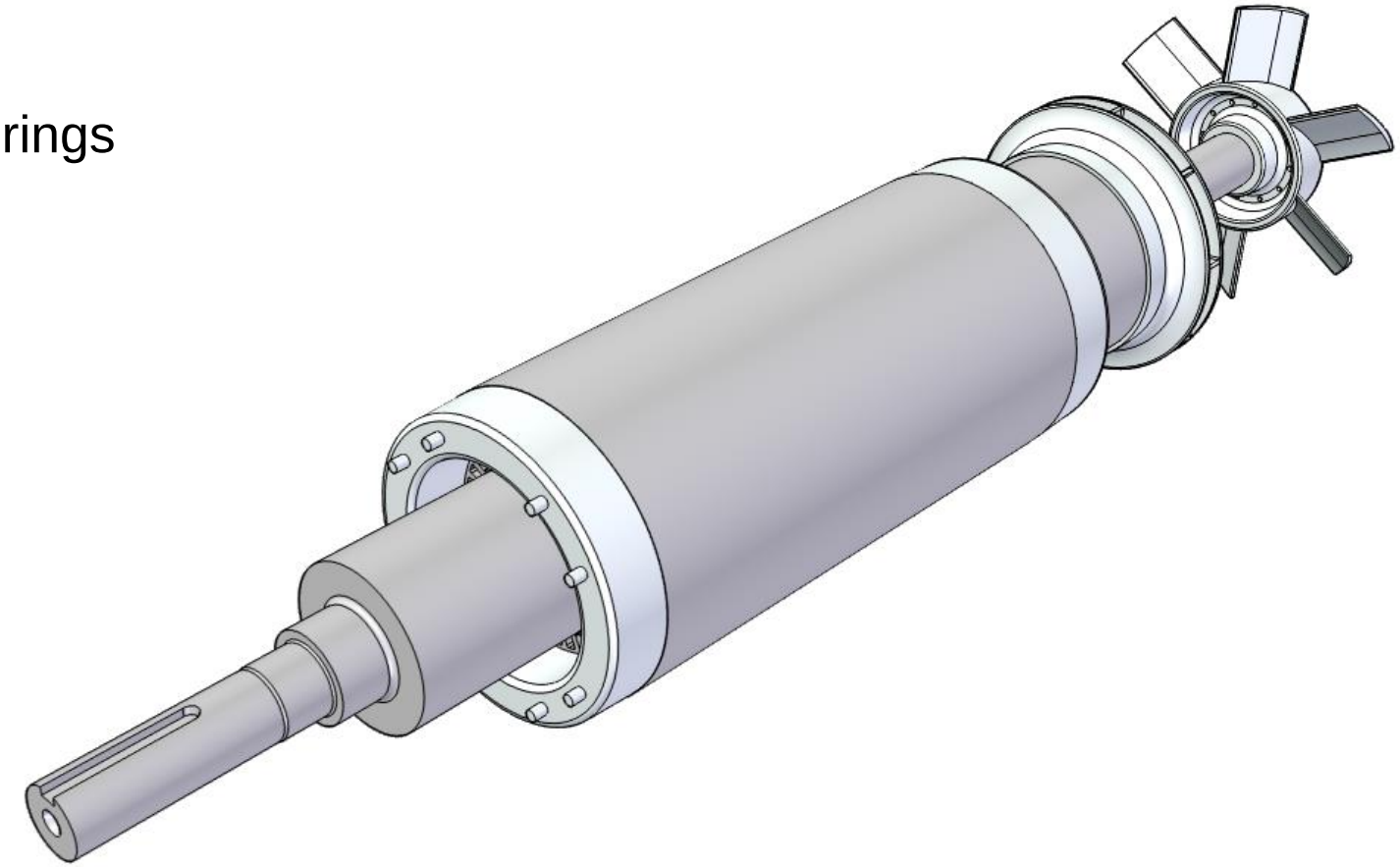


Figure E-1—Example of a polar plot of the relationship of cold to hot vibration complying with the requirements of section 4.3.3.11. This example is acceptable because the vibration is always less than 1.2 mil and the resultant vector change is less than 0.6 mil.

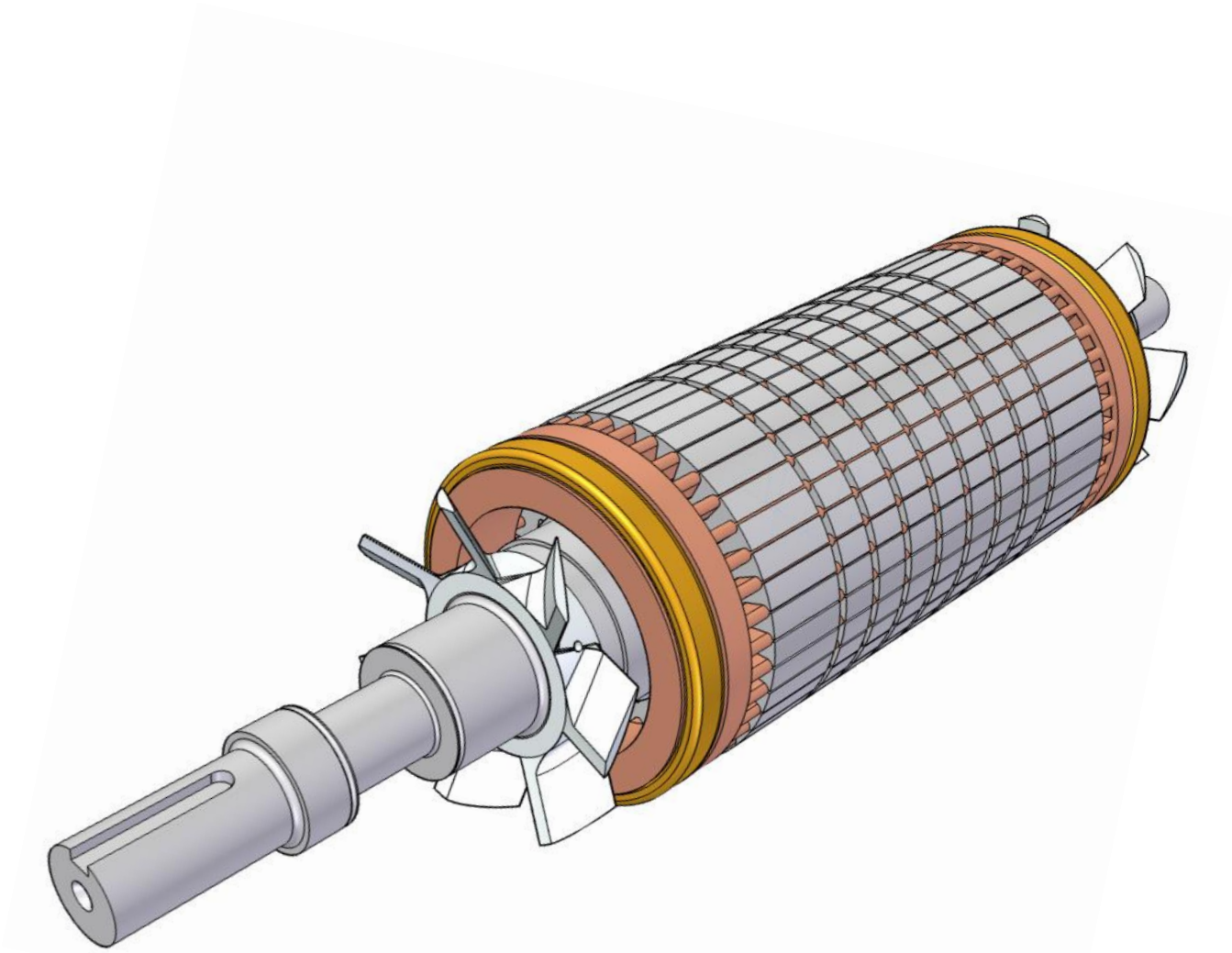
Aluminum Die Cast Rotors

- Shaft
- Laminated steel core
- Rotor bars/short circuit rings
- Air duct
- Internal fan
- External fan



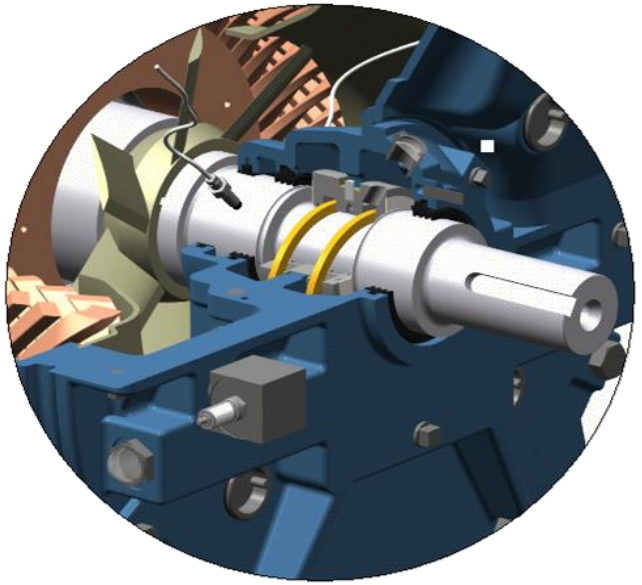
Copper Bar Rotor

- Shaft
- Laminated steel core
- Copper rotor bars
- Copper short circuit rings
- High tensile retaining rings
- Internal fans



API 541 4th Edition – Form-wound Squirrel Cage Induction Motors

- **Routine Testing**
  - Coil Surge comparison tests
  - Soft-foot check must be made prior to any mechanical running test
  - High-potential test
  - Polarization index
  - No-load bearing run + bearing temperature rise
  - Bearing inspection (sleeve bearings)
  - Vibration test



API 541 5th - Notable Changes

- Service life and Service Factor
- Insulation temperature limits
- Enclosures
- Accessories
- Shaft forgings
- Thermal capacity data
- Magnetic stator slot wedges
- Main terminal box features
- ASD design requirements
- Testing
- Data sheet & guide

Revised

API 541 5TH Edition – Basic Design

- Minimum service life / years of un-interrupted operation now required to be 25 / 5 years
  - Was 20 / 3 years (4.1.1)

- Machines shall have a 1.0 service factor
  - Stronger, clear wording (1.15 SF undesirable) (4.2.1.4)
  - Must address temperature rise if customer requires 1.15 SF.

- *If overload capacity is required, a higher nominal motor rating shall be selected*
- *Avoids operating motors above rated power, which increases winding temperatures and shortens motor life*

Revised

API 541 5TH Edition – Insulation Temperature Limits

- Meet class B temperature rise by resistance AND by RTD (4.3.1.1.b).

HP	Voltage	Method of Determination	Class A	Class B	Class F	Class H
HP < ∞	V < ∞	RESistance	60	**80**	105	125
HP ≤ 1500	V < ∞	DETector	70	**90**	115	140
HP > 1500	V ≤ 7000	DETector	65	85	110	135
HP > 1500	V > 7000	DETector	60	80	105	125

- RTDs measure “hot spot” temperature
- RTDs inserted between coils in the slots
- Average temperature determined by change of winding resistance
- Permitted hot spot rises are 0 to 10°C above average rises

- Occasionally average exceeds hot spot meaning hot spot is not the worst case
- Now required to meet the limits by both methods
- Ensures temperature limits are met throughout windings

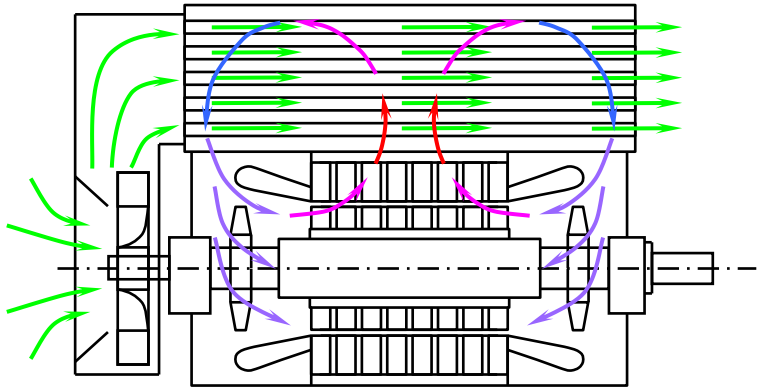
New

API 541 5TH Edition – Enclosure Changes

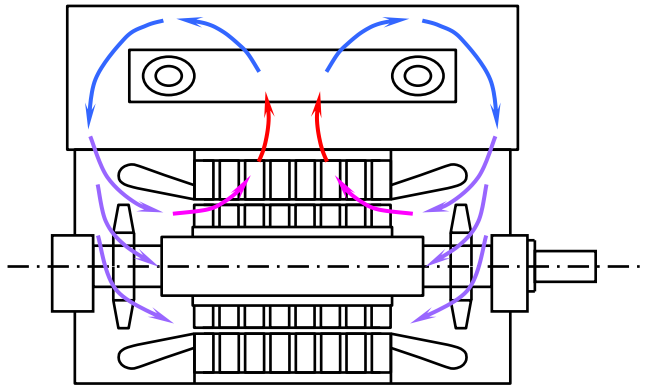
- **Totally enclosed motors required at 6kV and up** (4.4.1.1.f)
  - For example, TEFC, TEAAC or TEWAC
  - Default requirement
    - Free to specify open enclosure if good experience at site
    - Data sheet field added to give user place to waive this in favor of WP-II
  - Minimizes airborne contaminants
    - Reduced risk of electrical tracking
    - Reduced risk of early winding failure

- **TEWAC motors** are required to include a flow-sensing device and air RTD's (into and out of cooler) now as standard (4.4.1.2.4)

TEAAC/CACA



TEWAC/CACW



New

API 541 5TH Edition – Accessory Changes

- **New auxiliary terminal box design criteria**:
  - 316 SS required for Offshore and Marine duty (5.1.4.1)
  - Breather/Drain required (5.1.4.1)
  - Flexible conduit length is not to exceed 0.9 meters (5.1.12)
  - Customer conduit and cable entrances to be in bottom or sides only (5.1.13)

- **Bearing RTD's** are now required as standard on motors with hydrodynamic radial and thrust bearings (5.3.1)
  - 100 Ohm RTD unless otherwise specified on the motor data sheet.

New

API 541 5TH Edition – Accessory Changes

- **(3) Stator RTD's** per phase (5.2.1.2)
  - 2 per phase was former standard.

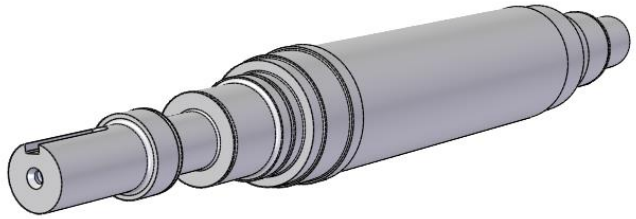
- Revised **Space Heaters** Criteria (5.4.1-3)
  - T3 temp code, not to exceed 160˚C lower

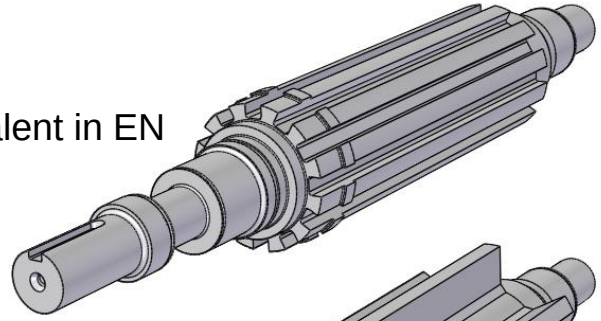
  (Space heaters remain a "when specified" option).

Revised

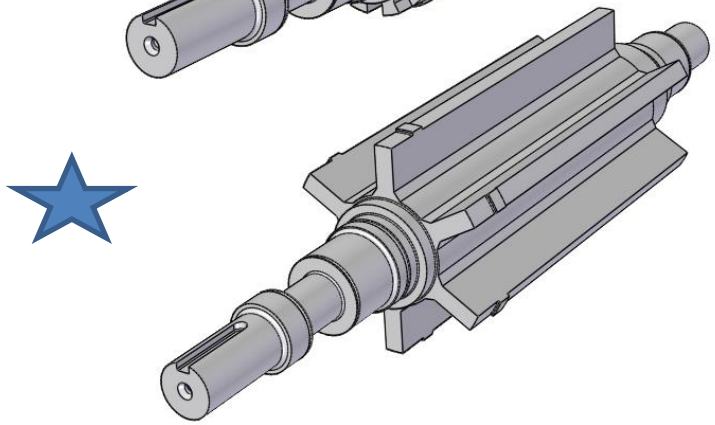
API 541 5TH Edition – Shaft Changes

- **4.4.5.1.3** Heat-treated forged steel shafts shall be used for machines having any of the following characteristics:
- a) finished shaft diameter 200 mm (8 in.) and larger;
- b) two pole machine;
- c) operation above the first lateral critical speed;
- d) driving a reciprocating load; or
- e) using a tapered hydraulic fit coupling.
- Hot-rolled shafts may be used for all other machines if the vendor can demonstrate a minimum of two years
- successful operating experience with the design in that application.
- **4.4.5.1.4 When specified**, the shaft and spider shall be machined from a one-piece heat-treated forging.
- **4.4.5.1.5** Heat-treated forged steel shafts shall be AISI 4000 series and comply with ASTM A668 or equivalent in EN 10250.





- ALL 2 pole motors (4.4.5.1.3.b)
  - Was 1000 hp & larger (4th)
  - All 2-poles (3rd)



Revised

Thermal Capacity Data

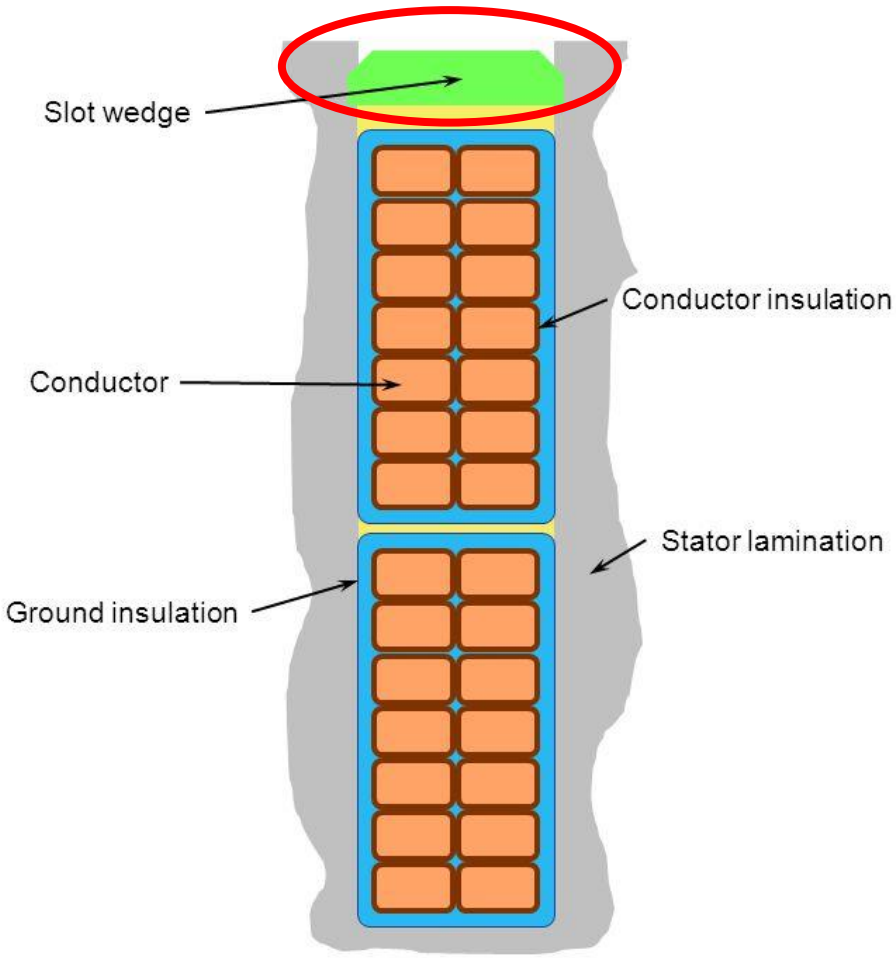
- Supplier now required to provide thermal capacity data, including:
  - Thermal limit curves
  - Acceleration curves
  - Required stop/running cool times after max starts

  ➢ Useful for programming motor protection relays

New

Magnetic Stator Slot Wedges (4.3.10)

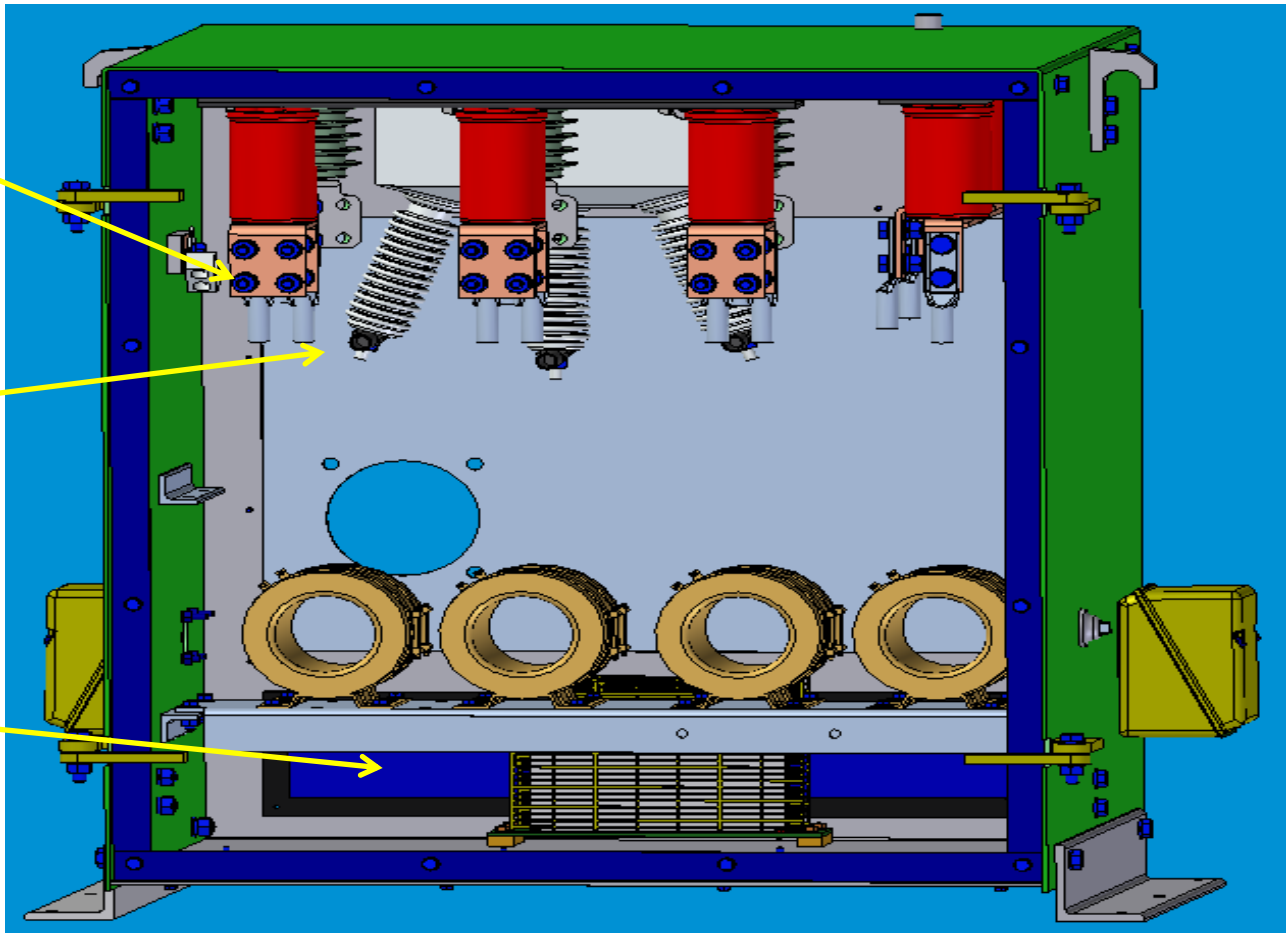
- Not previously been addressed
- Used by many vendors and can improve performance but some have durability issues
- Requirements –
  - Rigid and VPI'd in place, amorphous or composite construction, 10 year track record, 630 mm shaft height limitation
  - Advise use on proposal data sheet



New

API 541 5TH Edition - Main Terminal Box Features

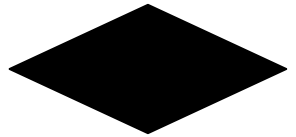
- NEMA Type II T-box with bus bar on standoffs now standard. (5.1.1)
  - Large box - may require support
  - Standoff insulators shall be either porcelain or cycloaliphatic resin material (not glastic).
- Optional Surge Capacitors now must be three separate single phase caps, vs. common ‘three-phase” single assembly surge cap (5.6.2.1)
  - “3-ph” version shown, is common
- Default requirement now for fault withstand capability / rupture disc in main t-box (5.1.2), *it was optional*



Revised

API 541 5TH Edition – ASD Motor Design

- Many new requirements and notes throughout the standard created for ASD applications and for purchaser information/review of application
- When specified, mutually agreed sound level on ASD (4.1.4)
- When specified, mutually agreed over-speed capability (4.1.5)
- Mutually agreed upon voltage and frequency ratings (4.2.1.2.3)
- Starting & Running, new note for ASD starting (4.2.3.3)
- Supply from ASD only, starting characteristics can differ from ACL requirements (4.2.4.5)
  - Note: Rotor and Stator temps
  - Note: Torsional oscillations from drive harmonics
  - Note: Damage due to improper application
- Purchaser to advise significant ASD harmonic content (4.3.1.2)
- Purchaser to advise ASD voltage spikes (4.3.1.2.1)
- Purchaser to advise ASD common mode voltage (4.3.1.2.2)
- Mutually agree on strategy to avoid structure resonances (4.4.2.1.1)
- Well damped rotor natural frequency if within speed range (4.4.6.1.2)



Symbol used to identify paragraphs in 541 with ASD related content

ASD CONDITIONS

American Petroleum Institute

INDUCTION MOTOR
API 541 5th Edition -- DATA SHEETS
U.S. CUSTOMARY UNITS
PURCHASER'S SELECTIONS
Bold Italics = Indicate Default Selection

JOB NO. _____ ITEM / TAG NO. _____
PURCHASE ORDER NO. _____
REQ. / SPEC. NO. _____
REVISION NO. _____ DATE _____ BY _____
REV. DATE _____ PAGE 1 OF 12 Rev

N.A.

Motor Power Source: ***Sine Wave Power*** ❍ ASD Power (complete below section) ❍

Adjustable Speed Drive (ASD) Conditions, if applicable (4.1.4; 4.1.5; 4.2.1.2.3, 4.3.1.2):

❍ ASD only operation (4.2.4.5) ❍ ASD+DOL Start capability ❍ ASD only w-Bypass

❍ Variable Torque Speed Range: Min Speed _____ RPM _____ ft-lb

❍ Constant Torque Speed Range: Min Speed _____ RPM

❍ Constant Power Speed Range: Max Speed _____ RPM _____ ft-lb

ASD Description and Information affecting motor design (Obtain from ASD Supplier; refer to D

ASD type / topology: _____

ASD Output Harmonics, describe and/or attach data (4.3.1.2): _____

ASD Maximum Voltage Spike Amplitude and Rise-Time at drive output (4.3.1.2.1): _____

ASD Maximum Common Mode Voltage (CMV) at drive output (4.3.1.2.2): _____

Other ASD information / motor requirements:

40 ❍ Abrasive Dust Protection, Open Enclosures (4.4.1.2.2,c): _____
41 ❍ Corrosive Agents in Environment, re: stress corrosion cracking (4.4.10.1.2): _____
42 Other: _____
43 _____

New

API 541 5TH Edition – Testing Changes

- Main T-Box requested to be mounted during performance testing (6.3.1.3)

- New Optional TEWAC Heat Exchanger Performance Test (6.3.5.5)
  - Test verifies performance during factory load testing
  - Verify flow and temperatures per specification

- New Optional Overspeed Test (6.3.5.6)
  - Test shall be run for two minutes at the overspeed listed in NEMA MG 1, Part 20; IEC 60034-1; or to the specified trip speed (including overshoot) of the connected equipment (whichever is greater).

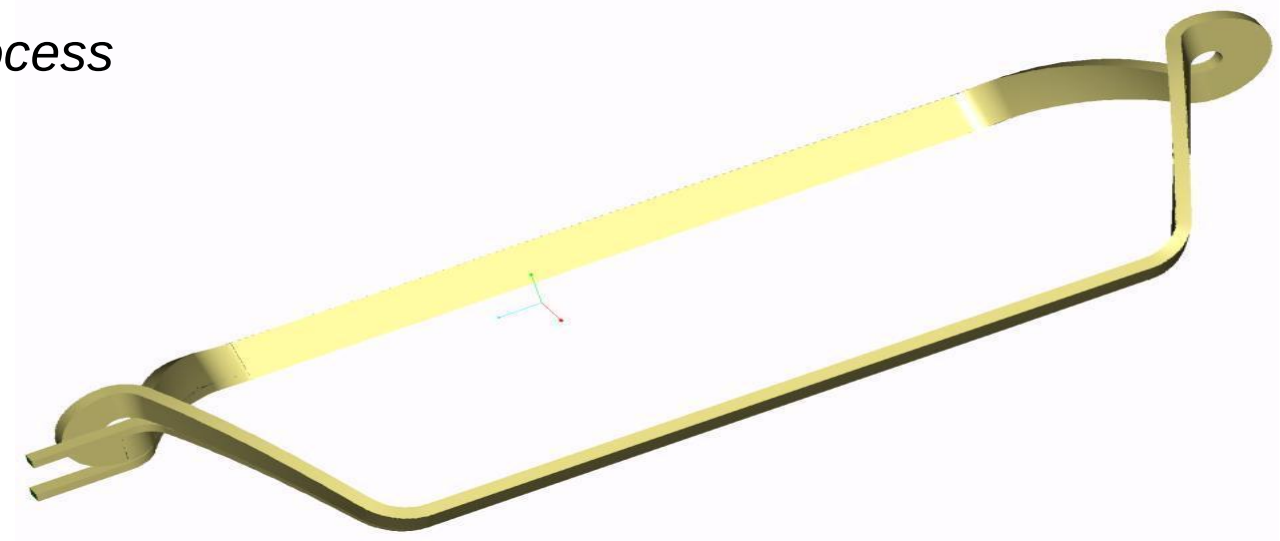
Revised

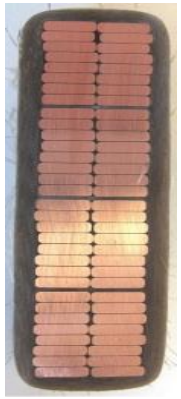
API 541 5TH Edition – Sample Coil Tests (6.3.4.2.1)

Optional tests to verify coil integrity and VPI process

(Two extra coils VPI'd with stator)

- Impulse test
  - Ground wall
    - 5 PU, 1.2 µs
  - Turn-to-turn
    - 2.0 & 3.5 PU 0.1 to 0.2 µs
    - Then test to destruction
- Cut coils (3 segments) and examine
- Coils that use semi-conductive coating in the slot section shall be subjected to a partial discharge test at rated line-to-neutral AC voltage.





New

API 541 5TH Edition – Stator Partial Discharge Testing (6.3.4.6)

- New option. 6kV & Higher
  - an off-line partial discharge test shall be performed on the stator windings, in accordance with Clause 10.2 of IEEE 1434 or IEC TS 60034-27.
  - Test voltage shall be 120 % of the rated phase-to-neutral voltage, maintained for at least five minutes.
  - The vendor shall provide the purchaser with partial discharge test data of similar machines with the same insulation system for comparison. The acceptance criteria shall be mutually agreed upon between the vendor and purchaser prior to performing the tests.

New

API 541 5TH Edition – Mount ½ Coupling (6.3.1.5)

- Vibration check test now required when ½ coupling hub is mounted by motor manufacturer

Revised

API 541 5TH Edition – Unbalanced Response Test (6.3.5.3)

- Mass moment simulator included during testing (option before)
- Vibration levels reduced, e.g. -
  - 3600rpm: 2.25 mils from 2.74 mils
  - 1800rpm: 2.25 mils from 3.87 mils
- First critical speed must match predicted (LCSA) results (within 5%)
  - If not, correct model


DRINK
COFFEE
Do Stupid
Things
Faster
with More
Energy

API 541 5th Edition

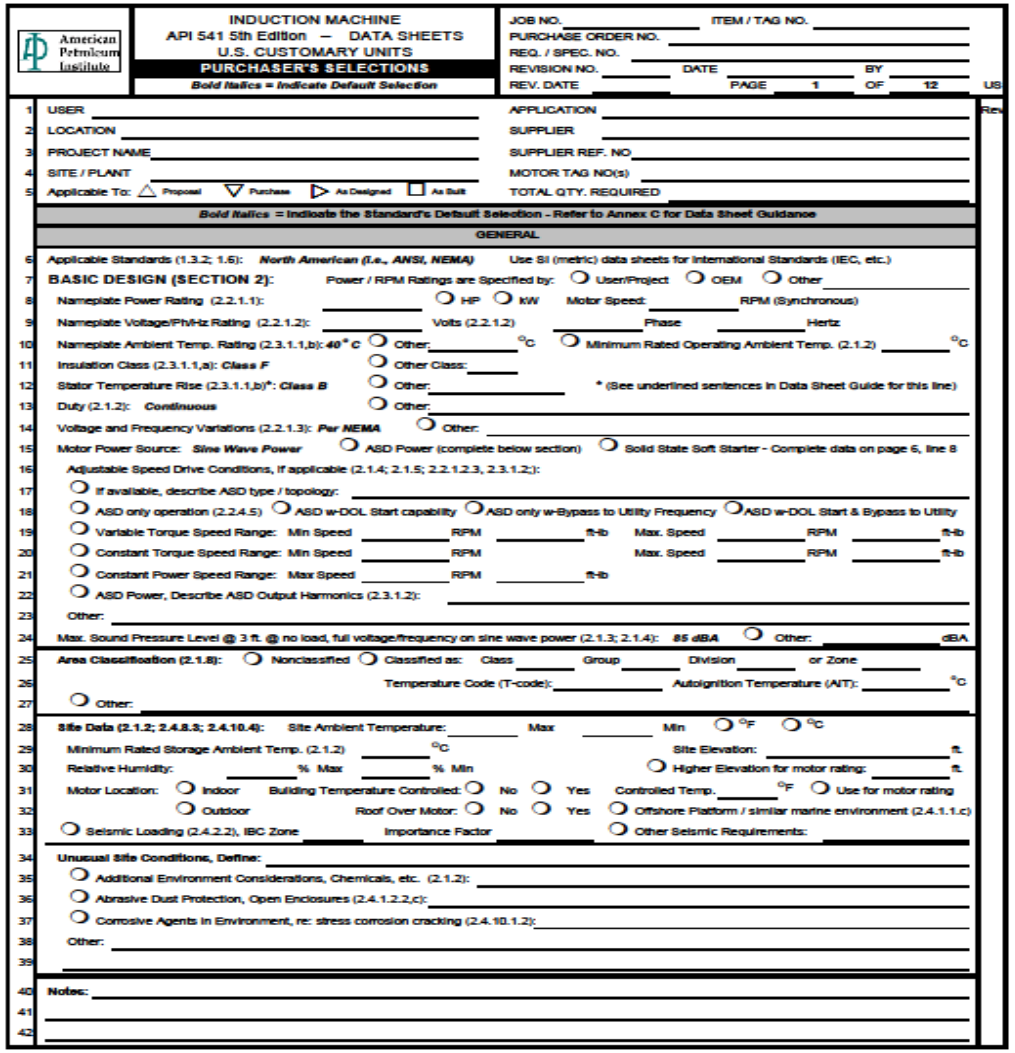
Data Sheets & Guide

Revised

API 541 5TH Edition - Data Sheets – Annex A

- Data Sheets completely redesigned

1.1.2 This standard requires the Purchaser to specify details and features. The Purchaser **shall** complete the data sheets in Annex A.



American Petroleum Institute

INDUCTION MACHINE
API 541 5th Edition – DATA SHEETS
U.S. CUSTOMARY UNITS
PURCHASER'S SELECTIONS
Bold Italics = Indicate Default Selection

JOB NO. ITEM / TAG NO.
PURCHASE ORDER NO.
REQ. / SPEC. NO.
REVISION NO. DATE BY
REV. DATE PAGE 1 OF 12 US

USER APPLICATION
LOCATION SUPPLIER
PROJECT NAME SUPPLIER REF. NO.
SITE / PLANT MOTOR TAG NO(s)
Applicable To: △ Proposal ▽ Purchase ▷ As Designed □ As Built TOTAL QTY. REQUIRED

Bold Italics = Indicate the Standard's Default Selection - Refer to Annex C for Data Sheet Guidance

GENERAL

Applicable Standards (1.3.2; 1.6): *North American (i.e., ANSI, NEMA)* Use SI (metric) data sheets for International Standards (IEC, etc.)

BASIC DESIGN (SECTION 2): Power / RPM Ratings are Specified by: ○ User/Project ○ OEM ○ Other

Nameplate Power Rating (2.2.1.1): ○ HP ○ kW Motor Speed: RPM (Synchronous)

Nameplate Voltage/Ph/Hz Rating (2.2.1.2): Volts (2.2.1.2) Phase Hertz

Nameplate Ambient Temp. Rating (2.3.1.1,b): *40° C* ○ Other: °C ○ Minimum Rated Operating Ambient Temp. (2.1.2) °C

Insulation Class (2.3.1.1,a): *Class F* ○ Other Class:

Stator Temperature Rise (2.3.1.1,b)*: *Class B* ○ Other: * (See underlined sentences in Data Sheet Guide for this line)

Duty (2.1.2): *Continuous* ○ Other:

Voltage and Frequency Variations (2.2.1.3): *Per NEMA* ○ Other:

Motor Power Source: *Sine Wave Power* ○ ASD Power (complete below section) ○ Solid State Soft Starter - Complete data on page 6, line 8

Adjustable Speed Drive Conditions, if applicable (2.1.4; 2.1.5; 2.2.1.2.3, 2.3.1.2.):

○ If available, describe ASD type / topology:

○ ASD only operation (2.2.4.5) ○ ASD w-DOL Start capability ○ ASD only w-Bypass to Utility Frequency ○ ASD w-DOL Start & Bypass to Utility

○ Variable Torque Speed Range: Min Speed RPM ft-lb Max. Speed RPM ft-lb

○ Constant Torque Speed Range: Min Speed RPM Max. Speed RPM ft-lb

○ Constant Power Speed Range: Max Speed RPM ft-lb

○ ASD Power, Describe ASD Output Harmonics (2.3.1.2):

Other:

Max. Sound Pressure Level @ 3 ft. @ no load, full voltage/frequency on sine wave power (2.1.3; 2.1.4): *85 dBA* ○ Other: dBA

Area Classification (2.1.8): ○ Nonclassified ○ Classified as: Class Group Division or Zone

Temperature Code (T-code): Autoignition Temperature (AIT): °C

○ Other:

Site Data (2.1.2; 2.4.8.3; 2.4.10.4): Site Ambient Temperature: Max Min ○ °F ○ °C

Minimum Rated Storage Ambient Temp. (2.1.2) °C Site Elevation: ft.

Relative Humidity: % Max % Min ○ Higher Elevation for motor rating: ft.

Motor Location: ○ Indoor ○ Outdoor Building Temperature Controlled: ○ No ○ Yes Controlled Temp. °F ○ Use for motor rating

Roof Over Motor: ○ No ○ Yes ○ Offshore Platform / similar marine environment (2.4.1.1.c)

○ Seismic Loading (2.4.2.2), IBC Zone Importance Factor ○ Other Seismic Requirements:

Unusual Site Conditions, Define:

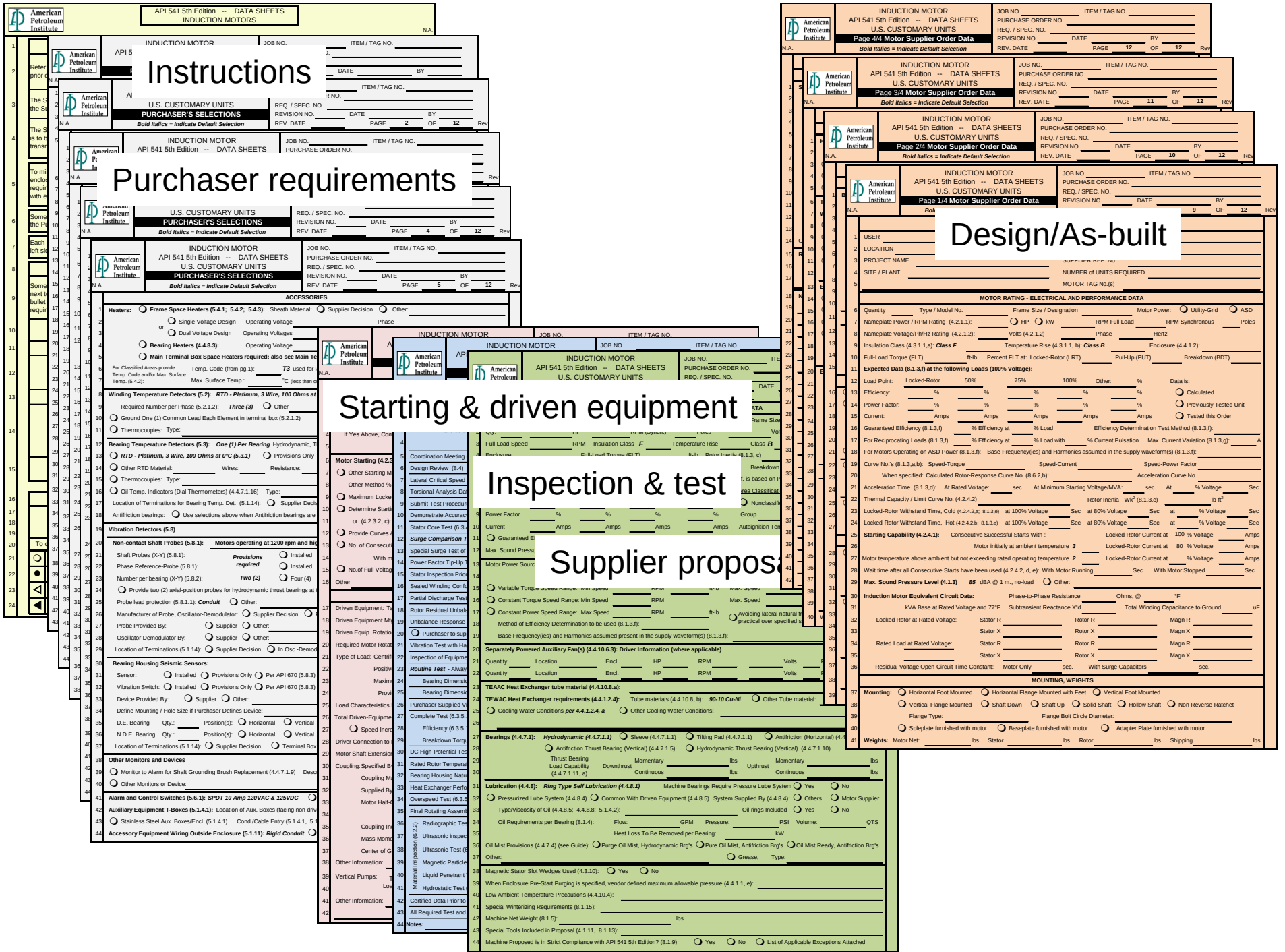
○ Additional Environment Considerations, Chemicals, etc. (2.1.2):

○ Abrasive Dust Protection, Open Enclosures (2.4.1.2.2,c):

○ Corrosive Agents in Environment, re: stress corrosion cracking (2.4.10.1.2):

Other:

Notes:

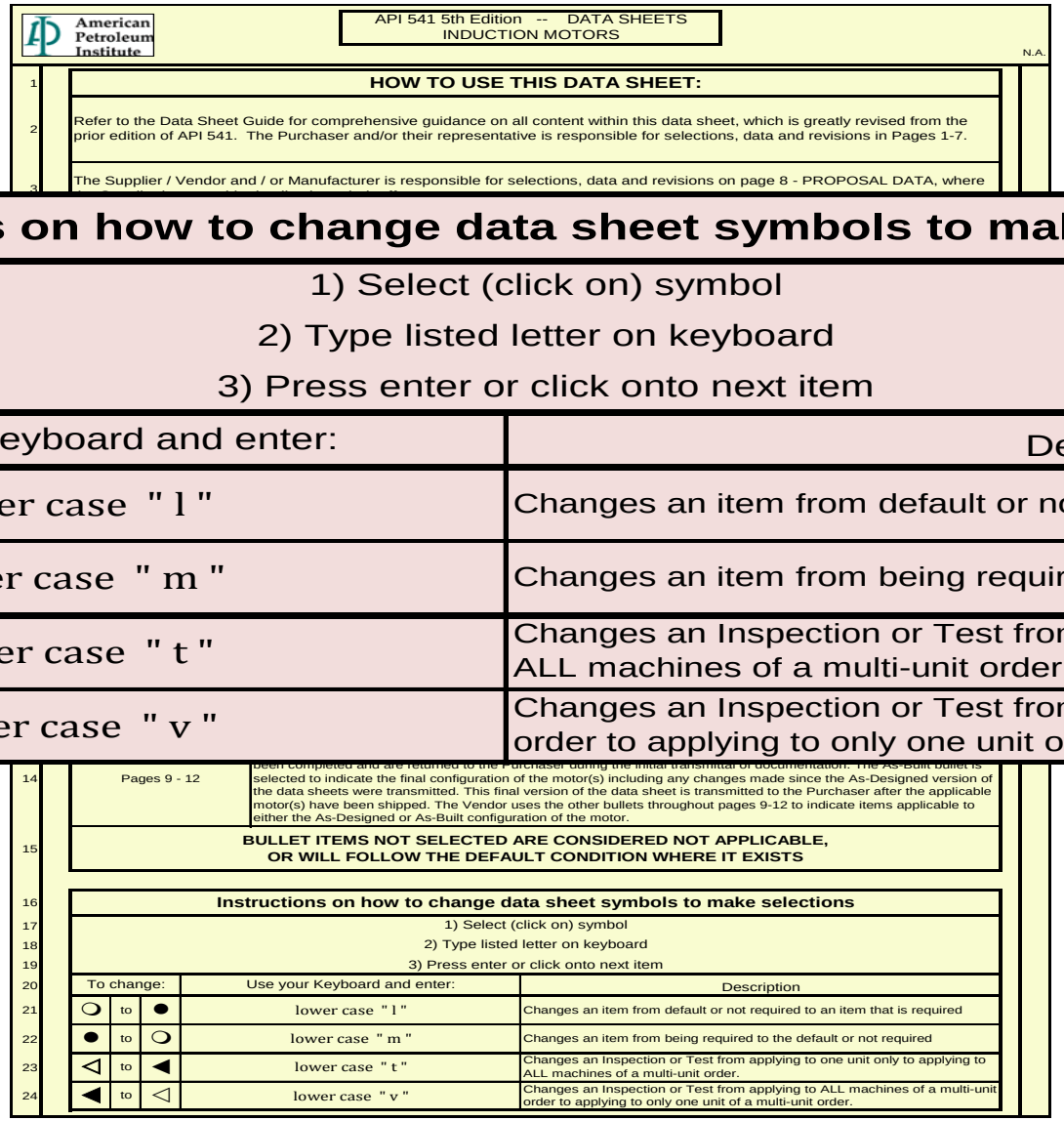

Instructions
Purchaser requirements
Starting & driven equipment
Inspection & test
Supplier proposa
Design/As-built
API 541 5th Edition -- DATA SHEETS
INDUCTION MOTORS
INDUCTION MOTOR
API 541 5th Edition -- DATA SHEETS
U.S. CUSTOMARY UNITS
PURCHASER'S SELECTIONS
Bold Italics = Indicate Default Selection
Page 4/4 Motor Supplier Order Data
Page 3/4 Motor Supplier Order Data
Page 2/4 Motor Supplier Order Data
Page 1/4 Motor Supplier Order Data
ACCESSORIES
MOTOR RATING - ELECTRICAL AND PERFORMANCE DATA
MOUNTING, WEIGHTS

Revised

Changes To Data Sheets

API 541 4th Edition	API 541 5th Edition
6 pages	12 pages
Purchaser responsible for 5 of 6 pages	Purchaser responsible for 7 of 12 pages
Purchaser data and supplier data interwoven	Separate purchaser and supplier sections
Multiple color-coded symbols, sections	One color, one symbol
Covered most 541 content	Covers all 541 content
Starting and driven equipment data on separate pages	Single page for starting and driven equipment data
Proposal data mixed throughout 4 pages	Proposal data all on single dedicated page
Contract data by Supplier mixed throughout 5 pages	All contract data on 4 dedicated pages

PAGE 0 – How to use



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API 541 5th Edition -- DATA SHEETS
INDUCTION MOTORS

N.A.

HOW TO USE THIS DATA SHEET:

Refer to the Data Sheet Guide for comprehensive guidance on all content within this data sheet, which is greatly revised from the prior edition of API 541. The Purchaser and/or their representative is responsible for selections, data and revisions in Pages 1-7.

The Supplier / Vendor and / or Manufacturer is responsible for selections, data and revisions on page 8 - PROPOSAL DATA, where

Pages 9 - 12 — been completed and are returned to the Purchaser during the initial transmittal of documentation. The As-Built bullet is selected to indicate the final configuration of the motor(s) including any changes made since the As-Designed version of the data sheets were transmitted. This final version of the data sheet is transmitted to the Purchaser after the applicable motor(s) have been shipped. The Vendor uses the other bullets throughout pages 9-12 to indicate items applicable to either the As-Designed or As-Built configuration of the motor.

BULLET ITEMS NOT SELECTED ARE CONSIDERED NOT APPLICABLE, OR WILL FOLLOW THE DEFAULT CONDITION WHERE IT EXISTS

Instructions on how to change data sheet symbols to make selections

1) Select (click on) symbol
2) Type listed letter on keyboard
3) Press enter or click onto next item

To change:			Use your Keyboard and enter:	Description
❍	to	●	lower case " l "	Changes an item from default or not required to an item that is required
●	to	❍	lower case " m "	Changes an item from being required to the default or not required
◁	to	◀	lower case " t "	Changes an Inspection or Test from applying to one unit only to applying to ALL machines of a multi-unit order.
◀	to	◁	lower case " v "	Changes an Inspection or Test from applying to ALL machines of a multi-unit order to applying to only one unit of a multi-unit order.

Instructions on how to change data sheet symbols to make selections

1) Select (click on) symbol
2) Type listed letter on keyboard
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◁	to	◀	lower case " t "	Changes an Inspection or Test from applying to one unit only to applying to ALL machines of a multi-unit order.
◀	to	◁	lower case " v "	Changes an Inspection or Test from applying to ALL machines of a multi-unit order to applying to only one unit of a multi-unit order.

PAGE 1 – RATING, SITE/ASD CONDITIONS, AREA CLASSIFICATION

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INDUCTION MOTOR
API 541 5th Edition -- DATA SHEETS
U.S. CUSTOMARY UNITS
PURCHASER'S SELECTIONS
Bold Italics = Indicate Default Selection

JOB NO. _____ ITEM / TAG NO. _____
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N.A.

1 USER _____ APPLICATION _____
2 LOCATION _____ SUPPLIER _____

Motor Power Source: ***Sine Wave Power*** ○ ASD Power (complete below section) ○

Adjustable Speed Drive (ASD) Conditions, if applicable (4.1.4; 4.1.5; 4.2.1.2.3, 4.3.1.2):

○ ASD only operation (4.2.4.5) ○ ASD+DOL Start capability ○ ASD only w-Bypass

○ Variable Torque Speed Range: Min Speed _____ RPM _____ ft-lb

○ Constant Torque Speed Range: Min Speed _____ RPM

29 **Area Classification (4.1.8):** ○ Nonclassified ○ Classified as: Class _____ Group _____ Division _____ or Zone _____

30 Temperature code (T-code): _____ Autoignition temperature (AIT): _____ °C

31 ○ Other: _____

ASD Output Harmonics, describe and/or attach data (4.3.1.2): _____

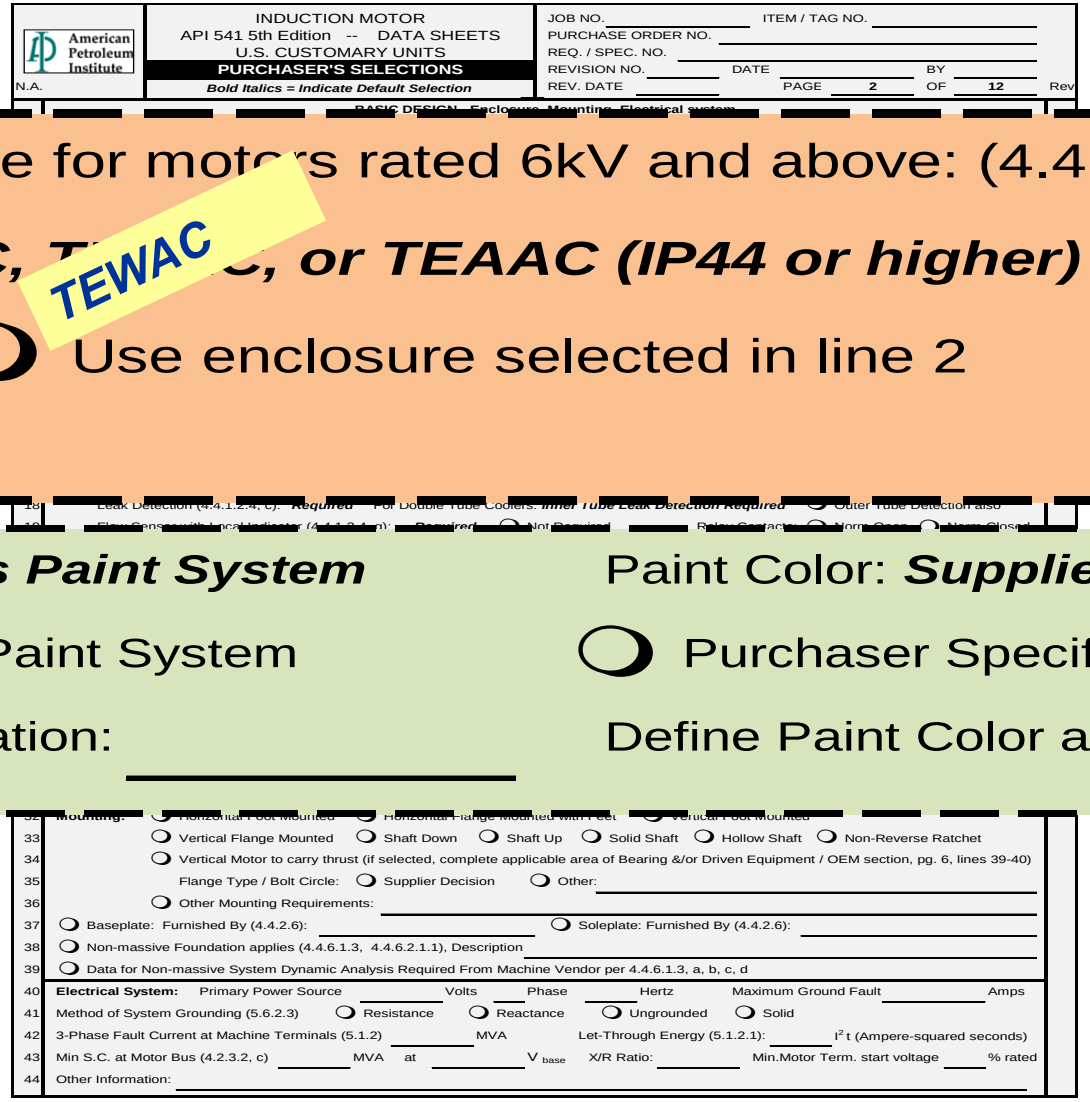
ASD Maximum Voltage Spike Amplitude and Rise-Time at drive output (4.3.1.2.1): _____

ASD Maximum Common Mode Voltage (CMV) at drive output (4.3.1.2.2): _____

Other ASD information / motor requirements:

41 ○ Corrosive Agents in Environment, re: stress corrosion cracking (4.4.10.1.2): _____
42 Other: _____
43

PAGE 2 – ENCLOSURE REQUIREMENTS



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PURCHASER'S SELECTIONS
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N.A.

BASIC DESIGN - Enclosure, Mounting, Electrical system

Enclosure for motors rated 6kV and above: (4.4.1.1,f):

TEFC, TEWAC, or TEAAC (IP44 or higher) or

❍ Use enclosure selected in line 2

Paint System: ***Supplier's Paint System***

❍ Purchaser Specified Paint System

Paint System Specification: _____

Paint Color: ***Supplier's Paint Color***

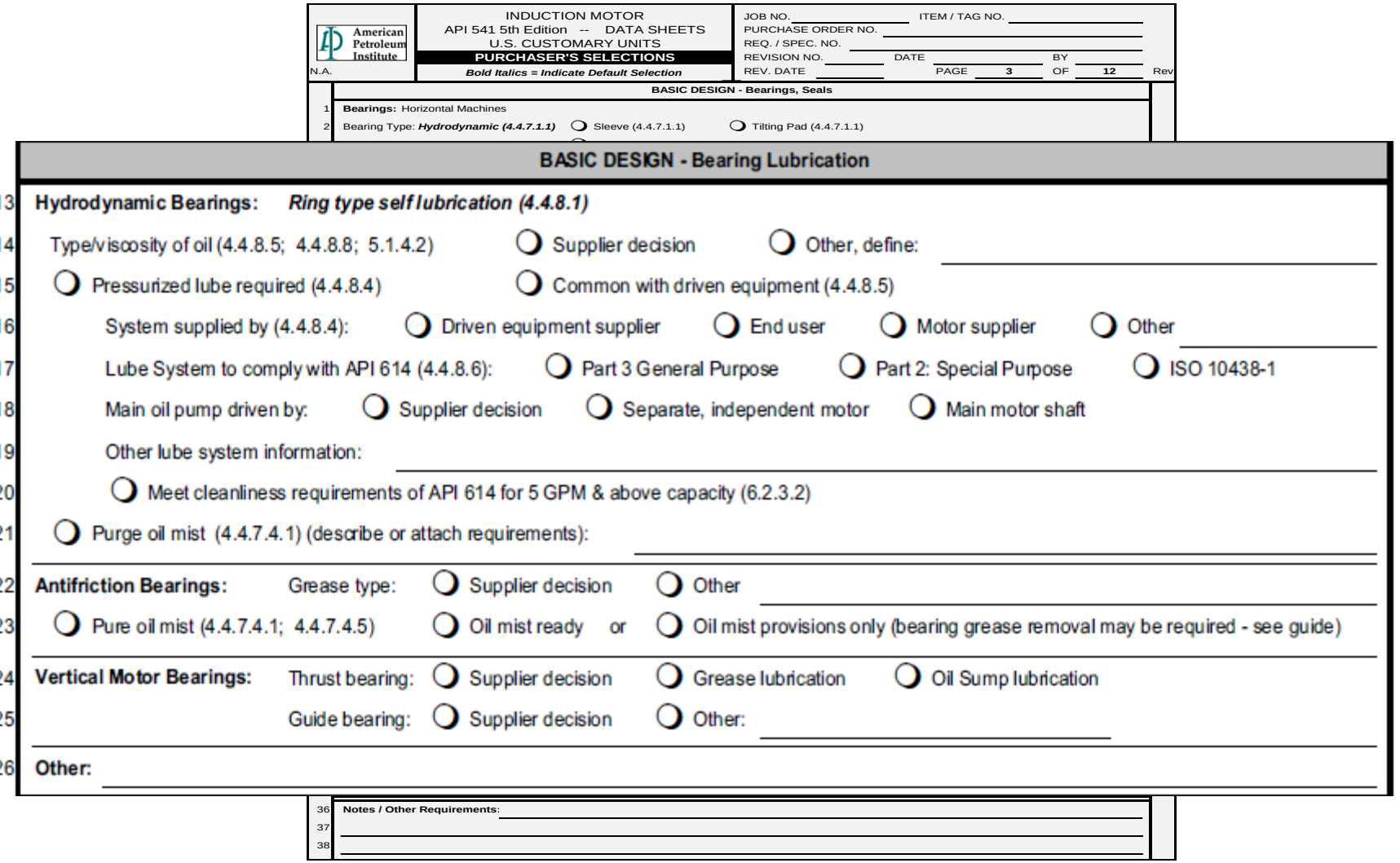
❍ Purchaser Specified Paint Color

Define Paint Color and Code: _____

Mounting: ❍ Horizontal Foot Mounted ❍ Horizontal Flange Mounted with Feet ❍ Vertical Foot Mounted
❍ Vertical Flange Mounted ❍ Shaft Down ❍ Shaft Up ❍ Solid Shaft ❍ Hollow Shaft ❍ Non-Reverse Ratchet
❍ Vertical Motor to carry thrust (if selected, complete applicable area of Bearing &/or Driven Equipment / OEM section, pg. 6, lines 39-40)
Flange Type / Bolt Circle: ❍ Supplier Decision ❍ Other: _____
❍ Other Mounting Requirements: _____
❍ Baseplate: Furnished By (4.4.2.6): _____ ❍ Soleplate: Furnished By (4.4.2.6): _____
❍ Non-massive Foundation applies (4.4.6.1.3, 4.4.6.2.1.1), Description _____
❍ Data for Non-massive System Dynamic Analysis Required From Machine Vendor per 4.4.6.1.3, a, b, c, d

Electrical System: Primary Power Source _____ Volts _____ Phase _____ Hertz Maximum Ground Fault _____ Amps
Method of System Grounding (5.6.2.3) ❍ Resistance ❍ Reactance ❍ Ungrounded ❍ Solid
3-Phase Fault Current at Machine Terminals (5.1.2) _____ MVA Let-Through Energy (5.1.2.1): _____ I^2t (Ampere-squared seconds)
Min S.C. at Motor Bus (4.2.3.2, c) _____ MVA at _____ V_{base} X/R Ratio: _____ Min.Motor Term. start voltage _____ % rated
Other Information: _____

PAGE 3 – BEARINGS, LUBRICATION



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PURCHASER'S SELECTIONS
Bold Italics = Indicate Default Selection

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N.A.

BASIC DESIGN - Bearings, Seals

Bearings: Horizontal Machines

Bearing Type: ***Hydrodynamic (4.4.7.1.1)*** ○ Sleeve (4.4.7.1.1) ○ Tilting Pad (4.4.7.1.1)

BASIC DESIGN - Bearing Lubrication

Hydrodynamic Bearings: ***Ring type self lubrication (4.4.8.1)***

Type/viscosity of oil (4.4.8.5; 4.4.8.8; 5.1.4.2) ○ Supplier decision ○ Other, define: ____

○ Pressurized lube required (4.4.8.4) ○ Common with driven equipment (4.4.8.5)

System supplied by (4.4.8.4): ○ Driven equipment supplier ○ End user ○ Motor supplier ○ Other ____

Lube System to comply with API 614 (4.4.8.6): ○ Part 3 General Purpose ○ Part 2: Special Purpose ○ ISO 10438-1

Main oil pump driven by: ○ Supplier decision ○ Separate, independent motor ○ Main motor shaft

Other lube system information: ____

○ Meet cleanliness requirements of API 614 for 5 GPM & above capacity (6.2.3.2)

○ Purge oil mist (4.4.7.4.1) (describe or attach requirements): ____

Antifriction Bearings: Grease type: ○ Supplier decision ○ Other ____

○ Pure oil mist (4.4.7.4.1; 4.4.7.4.5) ○ Oil mist ready or ○ Oil mist provisions only (bearing grease removal may be required - see guide)

Vertical Motor Bearings: Thrust bearing: ○ Supplier decision ○ Grease lubrication ○ Oil Sump lubrication

Guide bearing: ○ Supplier decision ○ Other: ____

Other: ____

Notes / Other Requirements: ____

PAGE 4 – ACCESSORIES

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U.S. CUSTOMARY UNITS

JOB NO. _____ ITEM / TAG NO. _____
PURCHASE ORDER NO. _____
REQ. / SPEC. NO. _____

❍ **Frame Space Heaters (5.4.1; 5.4.2; 5.4.3):** Sheath Material: ❍ Supplier Decision

or ❍ Single Voltage Design Operating Voltage _____

❍ Dual Voltage Design Operating Voltages _____ / _____

❍ **Bearing Heaters (4.4.8.3):** Operating Voltage _____

❍ **Main Terminal Box Space Heaters required: also see Main Terminal Box section,**

18 Antifriction bearings: ❍ Use selections above when Antifriction bearings are specified
19 **Vibration Detectors (5.8)**
20 **Non-contact Shaft Probes (5.8.1):** **Motors operating at 1200 rpm and higher** **Motors operating at less than 1200 rpm**

Non-contact Shaft Probes (5.8.1):	**Motors operating at 1200 rpm and higher**		**Motors operating at less than 1200 rpm**	
Shaft Probes (X-Y) (5.8.1):	***Provisions required***	❍ Installed	❍ Provisions	❍ Installed
Phase Reference-Probe (5.8.1):		❍ Installed	❍ Provisions	❍ Installed
Number per bearing (X-Y) (5.8.2):	***Two (2)***	❍ Four (4)	***Two (2)***	❍ Four (4)

39 ❍ Monitor to Alarm for Shaft Grounding Brush Replacement (4.4.7.1.9) Describe: _____
40 ❍ Other Monitors or Device: _____
41 **Alarm and Control Switches (5.6.1):** ***SPDT 10 Amp 120VAC & 125VDC*** ❍ Other: _____
42 **Auxiliary Equipment T-Boxes (5.1.4.1):** Location of Aux. Boxes (facing non-drive end): ❍ Left Side ❍ Right Side ❍ Other _____
43 ❍ Stainless Steel Aux. Boxes/Encl. (5.1.4.1) Cond./Cable Entry (5.1.4.1, 5.1.13): ❍ Bottom ❍ Left or ❍ Right Side facing non-drive end
44 **Accessory Equipment Wiring Outside Enclosure (5.1.11):** ***Rigid Conduit*** ❍ Other: _____

PAGE 5 – MAIN T-BOX REQUIREMENTS, MISCELLANEOUS

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U.S. CUSTOMARY UNITS

JOB NO. _____ ITEM / TAG NO. _____
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REQ. / SPEC. NO. _____

MISCELLANEOUS, SUPPLIER'S DATA

- Qty. Special Tools and Lifting Devices (4.1.11, 4.1.12, 4.4.2.14): _____
- Proof of Nonsparking, Corrosion-Resistant Fan (4.4.10.6.1)
- Separate Nameplate with Purchaser's Information - list below (4.4.11.4)
- Electronic Vibration Test Data - Define Digital Format below (6.3.3.17)

_____ _____

Packaging (6.4.1) Domestic Export Boxing Special Shipping Bearings (6.4.1, k) Outdoor Storage More Than Six Months (6.4.2)

Proposals (8.1) Typical Drawings & Literature with Proposal (8.1.8) Purchaser defined Efficiency Method (8.1.3,f): _____

- Separate Price For Each Test on Data Sheet (8.1.14)
- Packaged Price For All Tests on Data Sheet (8.1.14)
- Provide requirements for Special Weather & Winterizing Protection (8.1.15)
- Provide safe stall time calculation method and limits (4.2.4.3)
- Provide Quote for Supervision of Installation and Erection (8.1.17)
- Provide Quote for Start-Up Commissioning Service (8.1.17)
- Materials to be identified with ANSI, ASTM, or ASME Numbers (8.1.18): _____

Contract Data (8.3) Special Identification for Transmittals (8.3.2) Define below or specify where this information is to be found

Drawings (8.5) System of Units for Drawings / Data (1.3.1): U.S. / N.Am. Customary only SI (Metric) only U.S. (SI) SI (U.S.)

- Manufacturer To Supply Curve Data in Tabular Format (8.5.1) Define preferred Digital Format : _____
- Quantities of Documents & Drawings, and Documentation Schedule (or define source for this information) (8.5.1): _____
- After Purchaser Review of Drawings, Quantity of Certified Drawings to be provided (8.5.2): _____

Instruction Manuals (8.7) Quantity of Instruction Manuals to Provide (8.7.1) (Typically supplied in digital format): _____

- Detailed instructions and photo's, etc. for disassembly and inspection of bearings and seals (8.7.4, c)
- Photos showing machine assembly steps required; including each step of bearing assembly (8.7.5)
- Copies of Applicable Certifictions, including NRTL, Material Certications (including PMI), and other Certifications for the machine(s) (8.7.6)

Define any/all Certifications required, including materials:

43 Define any/all Certifications required, including materials: _____
44 _____

PAGE 6 – LOAD, STARTING, OEM DATA

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U.S. CUSTOMARY UNITS
PURCHASER'S SELECTIONS
Bold Italics = Indicate Default Selection

N.A.

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Load Torque and Inertia Requirements (4.2.2): ***Per NEMA MG 1-20*** or

❍ Per specified load curve & data (4.2.2.1,a)

Design Load Curve Condition: ❍ Unloaded (e.g. closed valve or damper)

Motor Starting (4.2.3): ***Across-The-Line Starting at 80% of Rated Voltage (4.2.3.1)*** or

❍ Other ATL % of rated voltage _____ %

❍ Other Starting Method (4.2.3.2, a): ❍ Autotransformer ❍ Captive Transormer

❍ Reactor ❍ Solid State Soft Starter ❍ ASD

If Soft Starter, define Percent Locked Rotor Current Limit during acceleration:

32 Supplied By: ❍ Purchaser ❍ Driven Equipment Supplier ❍ Motor Supplier ❍ Other: _____
33 Motor Half-Coupling Mounted By (4.4.9.4): (requires vibration test in 6.3.1.5 when Motor Supplier mounts half-coupling)
34 ❍ Purchaser ❍ Driven Equipment Supplier ❍ Motor Supplier ❍ Other: _____
35 Coupling Inertia (4.2.2.1, c): Wk^2: _____ $lb\text{-}ft^2$ or GD^2: _____ $kg\text{-}m^2$ (To be included in Total Inertia above)
36 Mass Moment of Coupling Half (4.4.6.2.1.1,f): _____ $lb\text{-}ft^2$ or _____ $kg\text{-}m^2$ (For damped unbal. response analysis)
37 Center of Gravity of Coupling Half - drawing reference or dimensions (6.3.5.3): _____
38 Other Information: _____
39 Vertical Pumps: Thrust Bearing Load (4.4.7.1.11, a) Downthrust Momentary _____ lbs Upthrust Momentary _____ lbs
40 Continuous _____ lbs Continuous _____ lbs
41 Other Information: _____
42

PAGE 7 – TESTING

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INDUCTION MOTOR
API 541 5th Edition -- DATA SHEETS
U.S. CUSTOMARY UNITS

JOB NO. _____ ITEM / TAG NO. _____
PURCHASE ORDER NO. _____
REQ. / SPEC. NO. _____

ANALYSIS, SHOP INSPECTION, AND TESTS

○	(m)	Indicates line item is not required
●	(l)	Indicates Purchaser required line item
◁	(v)	Indicates line item applies to only one machine in a multiple machine application/order

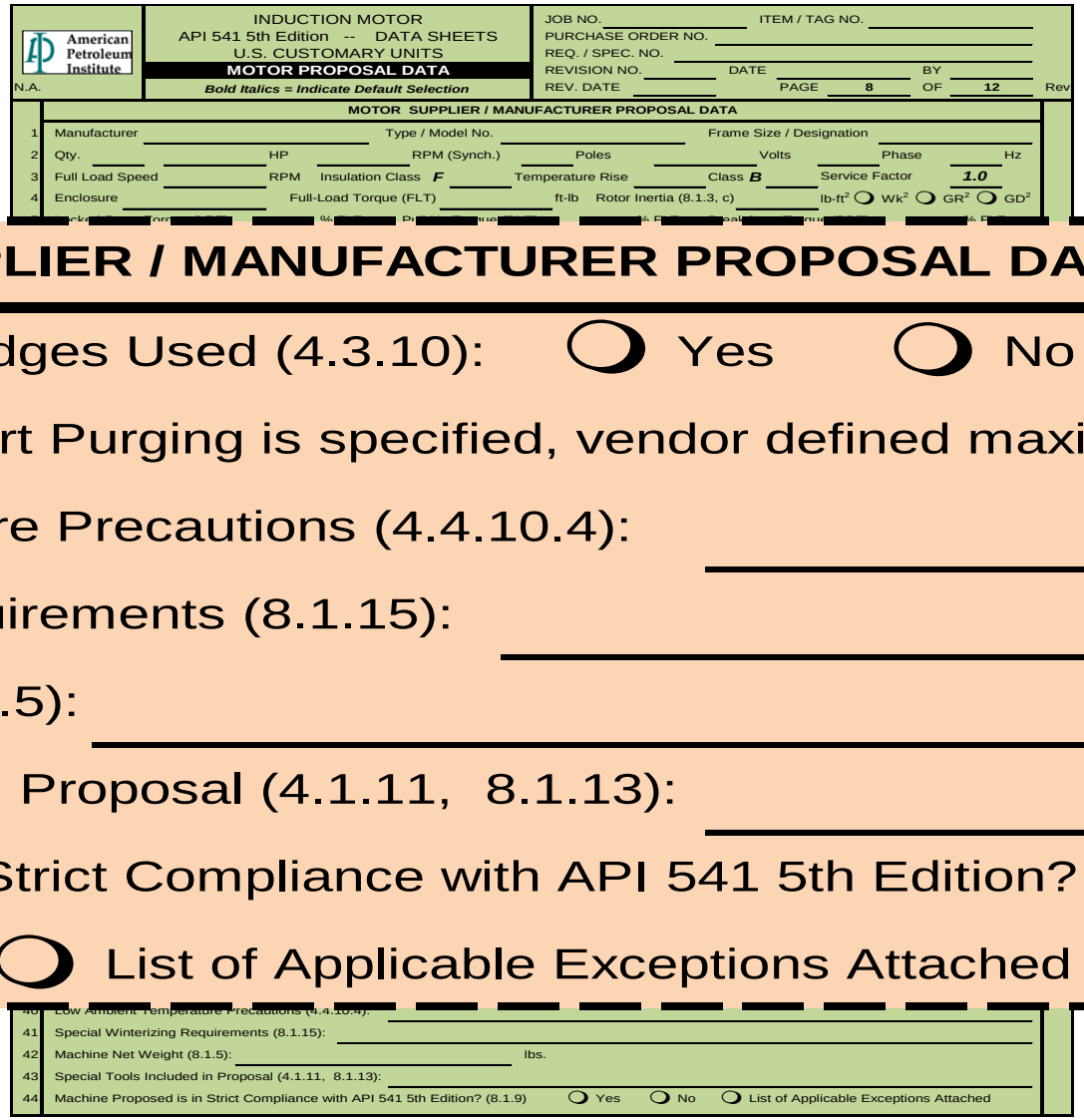
Unbalance Response Test (6.3.5.3) (Purchaser to select one of below options)

○ Purchaser to supply Half-Coupling or Mass Moment Simulator required for test

○ Purchaser to provide data for Supplier to obtain Simulator

34		Overspeed Test (6.3.5.6; 4.1.5)	○	◁	○	◁	○	◁
35		Final Rotating Assembly Clearance data storage (6.2.1.1, e)	○	◁				
36	Material Inspection (6.2.2)	Radiographic Test (6.2.2.2), Define Parts: _____	○	◁	○	◁	○	◁
37		Ultrasonic inspection of shaft forging (4.4.5.1.8; 6.2.2.3)	○	◁	○	◁	○	◁
38		Ultrasonic Test (6.2.2.3), Define Parts: _____	○	◁	○	◁	○	◁
39		Magnetic Particle Test (6.2.2.4), Define Parts: _____	○	◁	○	◁	○	◁
40		Liquid Penetrant Test (6.2.2.5), Define Parts: _____	○	◁	○	◁	○	◁
41		Hydrostatic Test (6.2.2.6), Define Parts: _____	○	◁	○	◁	○	◁
42		Certified Data Prior to Shipment (8.6.2, a)	○	◁				
43		All Required Test and Inspection Equipment (6.1.4) ***Provided by Supplier*** ○ Other: _____						
44		**Notes:** _____						

PAGE 8 – PROPOSAL DATA



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U.S. CUSTOMARY UNITS
MOTOR PROPOSAL DATA
Bold Italics = Indicate Default Selection

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N.A.

MOTOR SUPPLIER / MANUFACTURER PROPOSAL DATA

1 Manufacturer ____ Type / Model No. ____ Frame Size / Designation ____
2 Qty. ____ HP ____ RPM (Synch.) ____ Poles ____ Volts ____ Phase ____ Hz
3 Full Load Speed ____ RPM Insulation Class *F* ____ Temperature Rise ____ Class *B* ____ Service Factor *1.0*
4 Enclosure ____ Full-Load Torque (FLT) ____ ft-lb Rotor Inertia (8.1.3, c) ____ lb-ft² ❍ Wk² ❍ GR² ❍ GD²

MOTOR SUPPLIER / MANUFACTURER PROPOSAL DATA

Magnetic Stator Slot Wedges Used (4.3.10): ❍ Yes ❍ No

When Enclosure Pre-Start Purging is specified, vendor defined maximum allowable pressure (

Low Ambient Temperature Precautions (4.4.10.4): _____

Special Winterizing Requirements (8.1.15): _____

Machine Net Weight (8.1.5): _____ lbs.

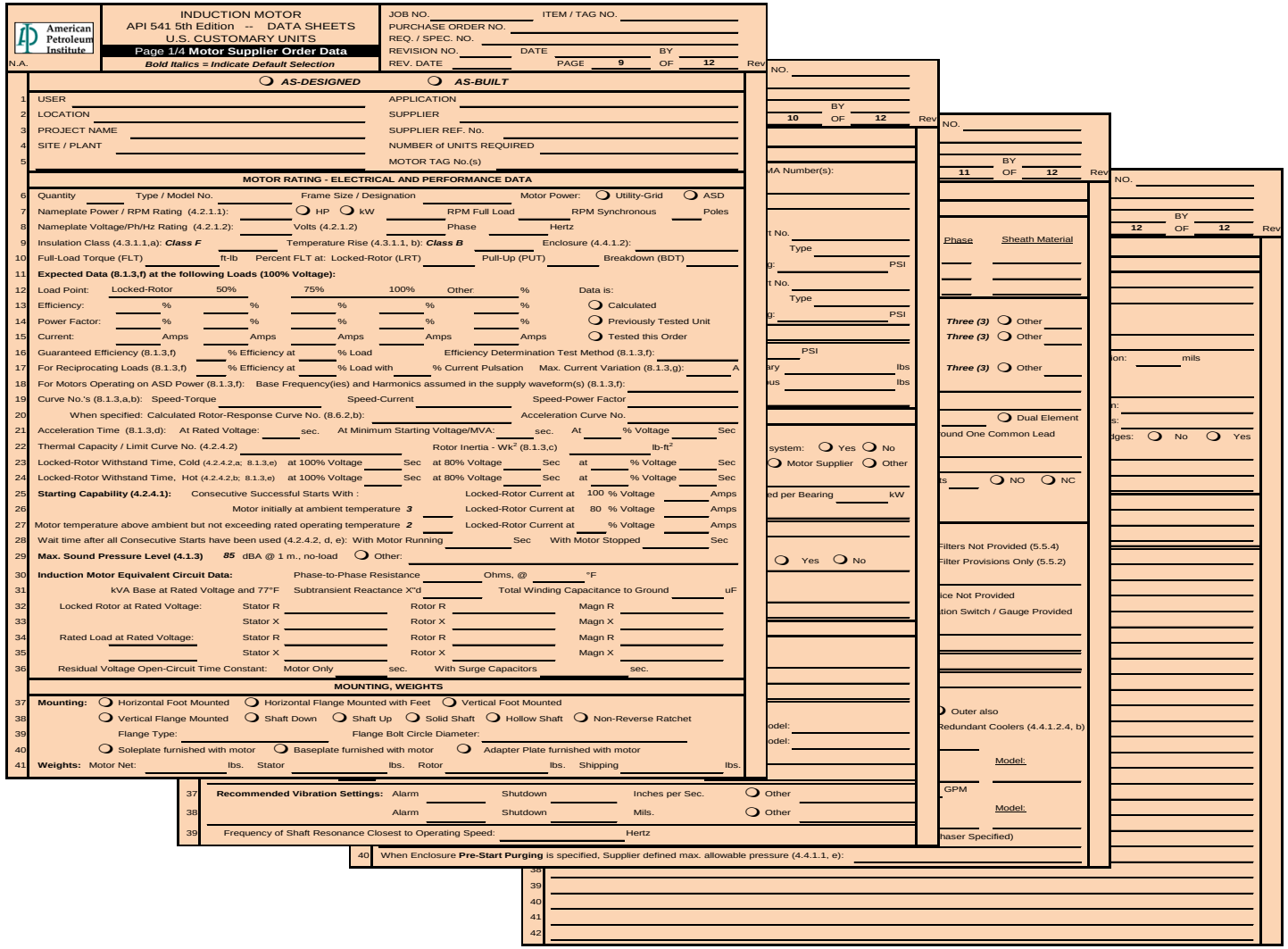
Special Tools Included in Proposal (4.1.11, 8.1.13): _____

Machine Proposed is in Strict Compliance with API 541 5th Edition? (8.1.9)

❍ Yes ❍ No ❍ List of Applicable Exceptions Attached

40 Low Ambient Temperature Precautions (4.4.10.4): ____
41 Special Winterizing Requirements (8.1.15): ____
42 Machine Net Weight (8.1.5): ____ lbs.
43 Special Tools Included in Proposal (4.1.11, 8.1.13): ____
44 Machine Proposed is in Strict Compliance with API 541 5th Edition? (8.1.9) ❍ Yes ❍ No ❍ List of Applicable Exceptions Attached

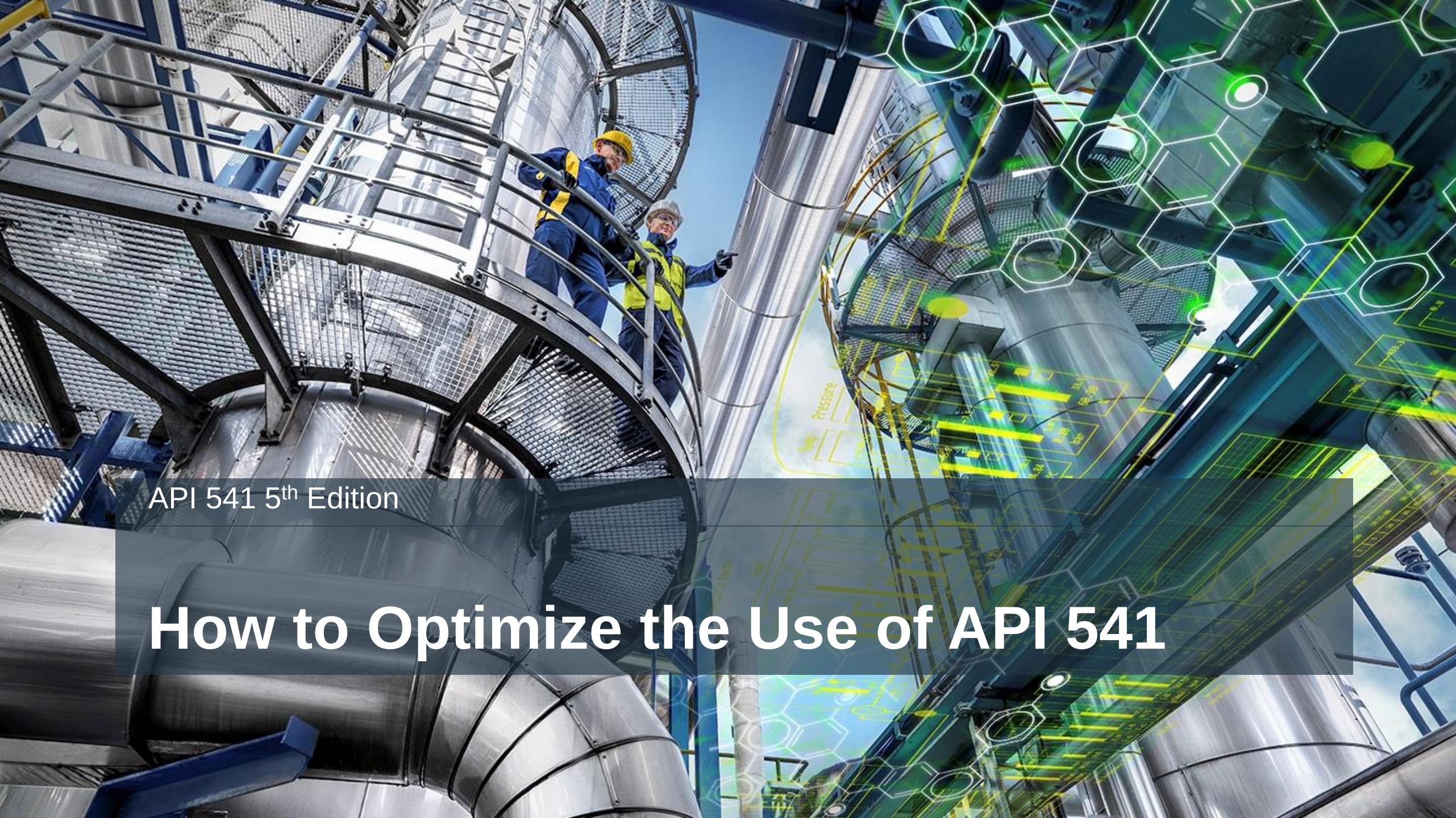
PAGES 9-12 – ORDER DATA



Revised

Data Sheet Guide – Annex 6

- Vastly revised vs. 4th edition
- Covers every data element on every line in all of the Purchaser's pages
- Gives recommendations based on working group experience
  - Could be used as the basis for a tutorial on API 541 and induction machines



API 541 5th Edition

How to Optimize the Use of API 541

How To Optimize Use of API 541

- Decide what is needed for the application
- Thoroughly complete the data sheet
- Evaluate manufacturer responses
- Maintain communications
- Test to ensure satisfactory results
- Install correctly
- Startup, operate, monitor and maintain properly

What Is Needed for the Application

- Power, speed and voltage
- Enclosure and cooling method
- Starting requirements
  - Electrical & mechanical
- Site Data
- Accessories
- Factory tests

Complete the Data Sheet

- Include essential information
  - It’s a requirement
- Use data sheet guide
- Equipment environment
- Mechanical system characteristics
- Electrical system characteristics
- Auxiliary systems

Evaluate Manufacturer Responses

- Review proposals in detail
- Ask clarification questions
- Look at alternatives
- Review/discuss any comments & exceptions
- Select the best option

Maintain Communications

- Face-to-face meetings
  - Coordination meeting
    - Verify scope of supply & expectations
  - Design review meeting
    - Finalize and confirm design
- Discuss & resolve issues before they affect the outcome

Test to Ensure Satisfactory Results

- Testing time/cost almost always worthwhile
- Test to suit application requirements
- Reduces risk of site problems
- Issues easier to remedy in factory
- Witness/observe where appropriate
- Consider impacts on the schedule

Install Correctly

- Suitable foundation requirements
- Installation & alignment
- Use OEM personnel when needed
- Review power system and protection
- Preservation prior to start-up

Startup, Operate, Monitor & Maintain

- Confirm start calculations
- Avoid excessive starts
  - There is a limit!
- Availability of spares
  - Commissioning & long term
- Monitor the motor condition
- Maintain per manufacturer’s instructions and user experience

Conclusions

- API 541 5th edition has significant changes
  - Insulation, vibration, protection & testing
- Aimed at improving reliability & durability
- Extensive data sheet and guide enhancements
  - Use the data sheets!
- Available now

Bart Sauer - Bio

- *Bart Sauer graduated from Case Western Reserve University (Cleveland, Ohio, USA) in 1989 with a Bachelor of Science degree in Mechanical Engineering. He has been an employee of Siemens Industry, Inc. at the ANEMA motor plant in Norwood, OH, since 1990, serving in roles as a Mechanical Product Engineer, Sales Application Engineer, and his current role as a Market Segment Manager for the oil and gas industry since 2009. In this role he serves as the technical lead for the API 547/541 specifications for Siemens AboveNEMA motors.*
- *Bart has been an author on three previous IEEE papers, and is a current committee member of the 2018 Cincinnati IEEE-IAS PCIC conference.*
- *Bart has 3 daughters and has been happily married for 27 years. He is an avid fisherman, a high school Sunday school teacher and a Canadian Olympic hockey team fan.*