

Specification for Squirrel Cage Induction Motor

(Cryogenic)

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Project Name : SK E&S Liquid Hydrogen Refueling Station Project

Owner : SK E&S

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CONTENTS

1. GENERAL	4
1.1 SCOPE	4
1.2 UNITS.....	4
1.3 MANUFACTURE'S DRAWING AND DOCUMENTS	4
1.4 GENERAL REQUIREMENTS	4
2. STANDARDS AND REGULATIONS	4
3. GENERAL CONDITIONS OF USE	6
3.1 SUPPLY CONDITIONS	6
3.2 SERVICE CONDITIONS.....	6
3.3 INSTALLATION CONDITIONS	6
3.4 CLIMATIC AND ENVIRONMENT CONDITIONS	6
4. GENERAL CONSTRUCTION REQUIREMENTS	8
4.1 CASING STRUCTURE	8
4.2 BEARINGS	8
4.3 BEARING LUBRICATION.....	8
4.4 SHAFT.....	8
4.5 ROTOR.....	8
4.6 MAGNETIC CIRCUIT	8
4.7 RESISTANCE TEMPERATURE DETECTORS	9
4.8 STATOR WINDINGS	9
4.9 EARTHING	9
4.10 TERMINAL BOXES	9
4.11 DIFFERENTIAL AND SURGE PROTECTION	10
4.12 IDENTIFICATION AND NAME PLATES	10
4.13 EXPLOSION PROOF ENCLOSURE	11
4.14 INSPECTION FOR SAFETY CERTIFICATION	11
4.15 LIFTING DEVICE	11

5. REQUIRED CHARACTERISTICS	11
5.1 NOISE LEVEL	11
5.2 VIBRATION	12
5.3 MOTOR EFFICIENCY	12
5.4 TORQUE	12
5.5 NUMBER OF STARTS	12
5.6 LOCKED ROTOR	12
5.7 OTHER CHARACTERISTICS.....	12
5.8 MOTOR SERVICE FACTOR	13
5.9 MOTOR STARTING	13
5.10 INSULATION	13
6. MOTOR DATA	13
7. TESTS AND VERIFICATIONS	14
7.1 MANUFACTURER TESTS	14
7.2 SHOP ACCEPTANCE TESTS.....	14
7.3 FIELD TESTS.....	15
7.4 ROUTINE TEST	15
7.5 COMPLETE TEST	15
7.6 STATOR TEST	16
8. LIMITS OF SUPPLY	16
9. MANUFACTURER GUARANTEE	16

1. GENERAL

1.1 Scope

This specification covers the medium and low voltage, squirrel caged submersible induction motors used for the cryogenic pumps to be installed at Liquid Hydrogen Refueling Station.

1.2 Units

Unless otherwise specified, international SI units shall be used for all drawings and documents to be submitted by the manufacturer.

1.3 Manufacture's drawing and documents

Drawing and documents shall be submitted according to the list of vendor document and schedule. Purchaser's approval for such drawings and documents shall not relieve manufacturer of his responsibility to meet all requirement of the purchase order.

1.4 General requirements

All submersible pump and electric motors shall be fabricated under the proven design by an approved motor manufacturer. All motor components shall be of materials suitable for use in the environment specified. All motors shall be designed to be operated in the environmental conditions specified.

2. STANDARDS AND REGULATIONS

Induction motors shall be designed, constructed, tested and performed in conformity with the following standards and regulation :

1) National Electrical Manufacturers Association (NEMA)

NEMA MG-1 (2016): Motors and generators

NEMA 250 (2018): Enclosures for Electrical Equipment (1000 Volts Maximum)

2) International Electro-technical Commission (IEC)

IEC 60034-1 (2017): Rotating electrical machines – Part 1: Rating and Performance

IEC 60034-5 (2020): Rotating electrical machines – Part 5 : Degrees of protection provided by the integral design of rotating electrical machines (IP code) – Classification

IEC 60034-8 (2014): Rotating electrical machines – Part 8: Terminal markings and direction of rotation

IEC 60034-9 (2007): Rotating electrical machines – Part 9: Noise limits

IEC 60034-12 (2016): Rotating electrical machines – Part 12: Starting performance of single-speed three-phase cage induction motors

IEC 60034-14 (2018): Rotating electrical machines – Part 14: Mechanical vibration of certain machines with shaft heights 56mm and higher – Measurement, evaluation and limits of vibration severity

IEC 60034-18-1 (2010): Rotating electrical machines – Part 18: Functional evaluation of insulation systems – General guidelines

IEC 60034-30-1 (2014): Rotating electrical machines – Part 30-1: Efficiency classes of line operated AC motors (IE code)

IEC 60044-1 (2003): Instrument Transformers – Part 1: Current Transformers

IEC 60079-0 (2017): Electrical apparatus for explosive gas atmospheres – Part 0: General requirements

IEC 60079-1 (2014): Electrical apparatus for explosive gas atmospheres – Part 1: Flameproof enclosures “d”

IEC 60079-2 (2014): Electrical apparatus for explosive gas atmospheres – Part 2: Equipment protection by pressurized enclosure “p”

IEC 60079-7 (2017): Electrical apparatus for explosive gas atmospheres – Part 7 : Increased safety “e”

IEC 60079-10-1 (2020): Electrical apparatus for explosive gas atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres

IEC 60079-11 (2011): Electrical apparatus for explosive gas atmospheres – Part 11: Equipment protection by intrinsic safety “i”

IEC 60079-14 (2013): Electrical apparatus for explosive gas atmospheres – Part 14: Electrical installations design, selection and erection

IEC 60079-15 (2017): Electrical apparatus for explosive gas atmospheres – Part 15: Type of protection “n”

IEC 60529 (2013): Degrees of protection provided by enclosures (IP Code)

3) American Petroleum Institute (API)

API std. 610 (2010): Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries

4) Institute of Electrical and Electronics Engineers (IEEE)

IEEE 112 (2017) : IEEE Standard Test Procedure for Polyphase Induction Motors and Generators

IEEE 242 (2001) : IEEE recommended practice for protection and coordination of industrial and commercial power systems

IEEE C57.13 (2008) : IEEE Standard Requirements for Instrument Transformer

5) Korean Industrial Standards (KS)

KS C 4202 (2020) : Low voltage three-phase squirrel-cage induction motors for general purpose

3. GENERAL CONDITIONS OF USE

3.1 Supply conditions

3.1.1 Squirrel cage electric induction motors designed to be supplied with :

- 1) Low voltage for up to 149.2kW (200HP) motors : 440V, 3Ph, 60Hz
- 2) Medium voltage for motors above 149.2kW (200HP) : 6.6kV, 3Ph, 60Hz
- 3) Space heater, if applied : 220V, 1Ph, 60Hz

3.1.2 Each motor shall supply its power rating and normal torque without exceeding the overheating limits specified in the standards. These conditions remain mandatory :

- 1) Plus or minus 10 percent of rated voltage with rated frequency.
- 2) Plus or minus 5 percent of rated frequency, with rated voltage.
- 3) A combined Variation in voltage and frequency of plus or minus 10 percent (sum of absolute value) of the rated values, provided the frequency variation does not exceed plus or minus 3 percent of rated frequency.
- 4) Motors shall be capable of direct full voltage starting or autotransformer starting or soft starter starting.

3.2 Service conditions

Motors are required to run in continuous operation for periods of several months. They shall also be capable of starting after being shut down for a month. Service conditions shall take into account climatic conditions, low temperature submerged service, unless otherwise specified.

3.3 Installation conditions

In all cases, motor enclosure shall be suitable for service at the location where the motor is installed. The explosion proof protection shall be suitably provided as per the hazardous area classification indicated on data sheet.

3.4 Climatic and environment conditions (HOLD)

3.4.1 Air temperature

- 1) Highest : 38.8°C
- 2) Lowest : -13.5°C
- 3) Mean : 14.5°C

3.4.2 Design temperature : -196°C ~ 50°C

3.4.3	Atmospheric pressure average	: 101.57kPa.a
3.4.4	Wind mean velocity	: 2.2m/sec
3.4.5	Design velocity	: 45m/sec @ 10m elevation, 10minutes average
3.4.6	Outdoor design conditions relative humidity	: 2 to 90%
3.4.7	Altitude	: +3.16m, from sea level
3.4.8	Ambient conditions	: salt laden air
3.4.9	Liquid temperature surrounding the motor	: -163 °C min.

4. GENERAL CONSTRUCTION REQUIREMENTS

The general requirements for construction are applicable to all types of enclosure. Special requirements are indicated in Section 5.

4.1 Casing structure

4.1.1 Motor enclosure

The motor enclosure and/or housing is to be an integral part of the pump. Therefore, the enclosure shall not have any special features that would effect the performance. The motor enclosure shall be furnished by the pump manufacturers.

4.1.2 Cooling method

The submerged electric pump motors shall be cooled by routing a sufficient amount of the pumped product liquid through the motor. There shall be no cooling fins, fans or fan blades on the rotor core or shaft.

4.2 Bearings

4.2.1 The bearings for the submerged electric motor are of a special design. They shall be open ball bearings made of compatible materials. These motor bearing are also the pump bearings and are to be sized to handle both the motor and pump loads.

4.2.2 Bearings are guaranteed for 25,000 hours of running in actual conditions of use.

4.3 Bearing lubrication

The lubricated medium will be the pump product liquid. The lubrication system design shall be such that a sufficient amount of the product liquid is routed through the bearings. Lubricating system and bearings are furnished by the pump manufacturer.

4.4 Shaft

The submerged electric motor is an integral part of the pump. Therefore, the motor shaft and the pump shaft are the same and couplings are not required.

4.5 Rotor

Rotor shall be squirrel cage laminated. After fabrication, the entire rotor assembly shall be coated with a suitable corrosion resistant finish.

4.6 Magnetic circuit

Magnetic circuit consists of insulated plates tightly bolted together so as to withstand mechanical stresses in the specified conditions of use.

4.7 Resistance Temperature Detectors

Resistance temperature detectors(Platinum) rated 100 ohms at 0°C, shall be provided in the motor slots, if applied or by request of Purchaser. RTD leads shall be routed in protected metallic conduit to a terminal block in a connection box separated with the main power terminal box. The conduit and connection box shall be provided by Manufacturer.

4.8 Stator windings

Stator windings are made of copper carefully with material in conformity with the insulation of class F and the rating of machines shall be based on a class B temperature rise for all parts of the machine windings when operating at rated power, rated voltage, rated frequency and having due regard for the environmental conditions specified in 3.4. The stator winding and end turns shall be adequately braced to withstand repeated full voltage starting. Windings shall be treated with the global impregnation method (vacuum, then pressure).

4.9 Earthing

Each motor shall be equipped with earthing terminations suitable for the mounting of M10-grounding bolts on the motor casing to allow connection of earthing conductor. Earthing points shall be protected against corrosion and designed to ensure that effective electrical and mechanical connections can be made. At least two separate grounding points at diagonally opposite ends on the motor casing shall be provided for medium voltage motors or motors over 100kW, while one grounding point for low voltage motors shall be furnished. The earthing symbol or legend shall identify this device. The Supplier's certified drawings shall show the location and type of grounding provisions for each frame size for Purchaser's approval.

4.10 Terminal boxes

- 4.10.1 Terminal boxes shall be of explosion proof type and be amply dimensioned and have the compression glands. Besides the connection terminals, they are equipped with one grounding terminal.
- 4.10.2 A terminal box of sturdy construction shall be provided with ample space (in case of MV motor, inner space of terminal box : minimum 500mm required between terminals and bottom hole) for connecting the cable(s) and constructed in such a way that the cable can be connected without a requirement for pulling the cable through a fixed opening in the box.

4.10.3 The size and type for entry hole of terminal box for MV/LV motor is as follows to connect the power cable(s). And terminal lugs shall be manufactured with this consideration too. The size and type for entry hole of terminal box of MV/LV motor will be provided after the cable size calculation.

4.10.4 Terminal box bottom side should be fabricated to installed inlet and outlet conduit.

4.11 Differential and surge protection

4.11.1 Motors over 1000kW (1340HP) shall be provided with differential and surge protection device. Manufacturer shall provide all wiring or bus work necessary for motor connections. A separate terminal box on or within the motor enclosure for mounting the equipment shall be provided.

4.11.2 CT's shall be provided for self-balancing type differential protection. The CT's shall be equipped in the motor terminal boxes so that the motor leads U1 and U2 pass through one CT, leads V1 and V2 through the second CT and W1 and W2 through the third CT, U2, V2, and W2 are then connected together for the "Wye" point.

4.11.3 Current transformer shall be dry or molded (complete coating of thermosetting synthetic resin) type which so rated and designed that they shall not sustain any damage due to through fault.

4.11.4 Current transformers for differential protection shall be Class PX in accordance with IEC 60044 or X Class in accordance with ANSI(IEEE std. C57.13)

Manufactures shall submit, for differential current transformers, the following information:

- Rated primary current
- Rated turn ratio (maximum error 25%)
- Rated knee point Voltage
- Maximum exciting current at the rated knee point and/or at a stated percentage
- Maximum resistance of secondary winding at a temp. of 75 °C
- Rated resistive burden
- Magnetizing (excitation) curve
- Error (rotation and phase displacement)

4.12 Identification and name plates

Nameplates shall be clearly stamped with information as described in Part 20 of NEMA MG 1-20.25 and in addition the following :

- Direction of rotation
- Motor weight
- Connection diagram
- Temperature class according to IEC 60079
- Zone classification according to IEC 60079

Rating nameplates of each motor shall be fixed bearing all information. Separate name plate indicating item No. of each motor with the dimension of 50 x 30mm shall be fixed near the rating plate. Motors installed in hazardous areas are equipped with the regular nameplates required for explosion proof equipments. All identification or regular nameplate shall be made of stainless steel.

4.13 Explosion proof enclosure

Parts to be installed at explosive hazardous area shall be of flame proof protection type and shall be conformity with the IEC 60079. For motors to be installed at hazardous area, the appropriate type can be used with the prior approval of Purchaser's. The temperature indicated on casing shall be lower than the spontaneous ignition temperature of the surrounding hazardous atmosphere depending on the proposed installation. Explosion-proof type motors are selected for the specified hazardous gas group which will be indicated on the data sheet. Manufacturer should submit the certification and inspection report to KOSHA, KGS or KTL for approval to purchaser before FAT.

4.14 Inspection for safety certification

The safety certification shall be obtained from KOSHA, KGS or KTL under article 34 of Korea industrial safety health law.

4.15 Lifting device

Lifting device shall be provided on all motors at balance point. Drilled and tapped holes in the enclosure case shall be dead-ended or permanently sealed. All motors shall have eye bolts, lifting lugs or extension pieces for hoisting. The IP rating of the motor shall be maintained regardless of any such eye bolts or lugs. Drawings shall be furnished by manufacture for information in construction of a motor lifting device and location of lifting points.

5. REQUIRED CHARACTERISTICS

The technical requirements and ratings of the motors shall comply with IEC 60034.

5.1 Noise level

Maximum permissible noise level is the value defined, by IEC 60034-9. By extension, the maximum value shall be taken into account, without power limitation, for the rpm considered.

5.2 Vibration

- 5.2.1 Balancing of rotating parts shall correspond to the maximum permissible total vibration amplitude defined by IEC 60034-14.
- 5.2.2 By extension, maximum values shall be maintained for power rating higher than those indicated by IEC rules.

5.3 Motor Efficiency

For low-voltage 3-phase motors, the motor efficiency shall be applied IE3 (Premium Efficiency) as minimum in accordance with IEC 60034-30 referred to Attachment #3.

5.4 Torque

- 5.4.1 For motors up to and including 500kW (670HP) and having the speed higher than 1500rpm
 - Locked rotor torque shall be at least equal to full load torque.
 - Pull-up torque during starting shall be at least equal to full load torque.
 - Breakdown torque should be at least equal to twice the full load torque.
- 5.4.2 For motors of larger than 500kW (670HP) or with the speed lower than 1500rpm, values of locked rotor torque, pull-up torque and breakdown torque shall be adapted depending on load torque of the driven machine and on permissible voltage drop in the system.

5.5 Number of starts

The motor shall be designed and manufactured in accordance with NEMA MG1-20.12 requirements for successive starts, to start and accelerate the driven load as defined on the driven load speed-torque curve.

5.6 Locked rotor

All the motors shall be capable of enduring the required locked rotor current for the specific start up duration as per the speed- torque characteristics of the connected load. Minimum duration which motors will be capable of withstanding full voltage with locked rotor is (when starting hot) :

- 4 seconds for low voltage motors,
- 6 seconds for medium voltage motors

5.7 Other characteristics

Taking Into account that above required characteristics have priority, motors shall have:

- Lowest possible starting current surges.
- Highest possible power factors
- Highest possible efficiencies as per section 5.3.

5.8 Motor service factor

Motor shall be complied with the provisions of the standard NEMA MG 1-12.51 in case the specification of the motor are not mentioned by client. The service factor shall be utilized for special situations where loading will exceed full-load rating in short-time emergency condition and not for continuous operation. (minimum standard 1.0 service factor)

5.9 Motor starting

5.9.1 The starting current at full voltage shall not exceed 700% of rated current for LV motors, 600% of rated current for MV motors.

5.9.2 During motor starting, the voltage level at the motor terminals should be maintained minimum 80% of rated voltage.

5.10 Insulation

5.10.1 Motor windings shall be suitably treated so that the insulation is moisture resistant and adequate for exposure to severe atmospheric conditions. Motor shall have fully sealed insulation system as described in NEMA Standard MG1-1.27.2

5.10.2 The stator insulation shall be vacuum pressure impregnated after the stator has been wound, wedged, connected and the bracing system installed.

5.10.3 The strand insulation and turn insulation shall be designed to withstand excessive switching surges caused by open-close operation of vacuum circuit breaker. The stator winding insulation shall be designed to withstand an electrical impulse voltage within the envelope defined in Fig. 1 of IEEE 522.

5.10.4 One or both bearings shall be insulated to prevent flow of shaft current, unless otherwise protected by other means.

6. Motor Data

The following motor design data shall included:

- 1) Nameplate data as per section 4.12.
- 2) Locked-rotor, pull-up and breakdown torques (speed vs. torque curves)
- 3) Efficiency at $\frac{1}{2}$, $\frac{3}{4}$, and full load
- 4) Power factor at locked-rotor, no load, $\frac{1}{2}$, $\frac{3}{4}$, and full load
- 5) Current at locked-rotor, no load, $\frac{1}{2}$, $\frac{3}{4}$, and full load
- 6) Sub-transient reactance, X''_d
- 7) Open-circuit time constant
- 8) Acceleration time based on specific load condition at 100% V_n and at 80% V_n

- 9) Motor LRA and PF at 100%Vn and at 80%Vn
- 10) Motor curves: Motor and Load Speed-Torque, Motor Speed-Current, Speed-Power Factor,
- 11) Time-Current & Thermal Limit Curve at 100% Vn and at 80% Vn
- 12) Hot and cold safe stall time at 100% Vn and at 80% Vn
- 13) Maximum number of starts per hour and minimum time between starts at motor cold & at motor hot
- 14) Motor cool time constant when motor running and when motor stopped
- 15) Winding RTD type, recommended RTD trip and alarm temperature settings
Bearing RTD type, recommended RTD trip and alarm temperature settings
- 16) Maximum and recommended Power Factor Correction Capacitor rating
- 17) Rotor inertia GD2 in N.m2 or WK2 in lb.ft2
- 18) Bearing reference data including part numbers
- 19) Cooling data and lubrication requirements if applicable
- 20) Installation, maintenance and operating instructions, including drawings, illustrations, complete parts lists
- 21) Winding data sufficient to permit coil manufacture
- 22) Rotor removal method
- 23) Expected sound power level at no-load

7. TESTS AND VERIFICATIONS

Test shall be in accordance to those described by NEMA MG 1-20, ANSI/IEEE std. 112 and IEEE 522. Motors are accepted if the results of the series tests are in conformity with the characteristics indicated in the specifications within the tolerance limits.

7.1 Manufacturer tests

These are the tests carried out on the different types of motors which the manufacturer performs on prototypes or during fabrication, for which he provides an "As built" certificate or test report.

7.2 Shop acceptance tests

Shop acceptance tests are witnessed by a owner and/or purchaser or its representatives. They are normally restricted to :

- 1) Visual inspection
- 2) Measurement of winding resistance at ambient temperature and at the temperature which will exist prior to start-up (when not recently run).
- 3) High voltage test plus insulation resistance before and after pump performance test.
- 4) Measurement of starting current and run up time under cold conditions.

- 5) Pump start test at minimum voltage and operating temperature.
- 6) Dielectric tests, high potential test.

Note : It is recognized that any running tests of the motor can only be conducted after the pump is assembled, and submerged in the test tank. Additional tests may be required, in this case they will be indicated in the purchase order. A test report shall be made of these acceptance tests.

7.3 Field tests

Before being placed in service each motor shall be checked, if possible not coupled to driven machine, for :

- 1) Insulation
- 2) Direction of rotation

7.4 Routine Test

Each motor shall be given a routine (commercial) test to demonstrate that the motor is free from mechanical and electrical defects. Test methods and reporting shall follow ANSI/IEEE std.112, and NEMA MG-1-20.26. Testing shall include :

- 1) Measurement of no-load current (each phase)
- 2) Measurement of nominal no-load speed
- 3) Determination of locked-rotor current
- 4) High-potential test
- 5) Measurement of winding DC resistance
- 6) Measurement of vibration
- 7) Bearing inspection as per API std.541, section 4.3.2.1.j

7.5 Complete Test

Unless otherwise specified, motors rated 1000hp and larger shall be given the following tests. Where it can be demonstrated to the satisfaction of Purchasor's representative that an identical motor design has previously been built and tested, these tests may be omitted. Where a number of identical motors are supplied, and when approved by the Purchasor's representative, testing shall be done on one motor only. These tests shall include :

- 1) Determination of efficiency and power factor at $\frac{1}{2}$, $\frac{3}{4}$, and full load
- 2) Determination of locked-rotor power factor
- 3) Determination of full-load current and slip
- 4) Determination of locked-rotor and breakdown torque
- 5) Temperature at motor full load
- 6) Bearing temperature rise at motor full load

7) Vibration readings during load test

Performance shall be determined by methods stated in ANSI/IEEE std. 112, except Efficiency Test Method A. The method used in determining efficiency shall be stated in the test report. Heat run test shall be conducted in accordance with section 6 of ANSI/IEEE std.112. Actual loading method (e.g., method B(dynamometer method), method C(pump-back method) and method E (input measurement method)) shall be used for making the heat run test. Other loading methods (e.g., dual-frequency method, forward Stall Test and Reduced Voltage Rated Current method) shall be approved at time of purchase order by the Purchaser's representative. The testing shall continue until four equal subsequent temperature readings are obtained over a one hour period after the motor stator has reached full load operation temperature.

7.6 Stator Test

When specified, surge comparison test shall be made of turn insulation in the fully wound stator just prior to making up coil-to-coil connections per IEEE std. 522. Peak voltage shall not exceed the motor rated RMS voltage. When specified, winding immersion test shall be performed per NEMA MG-1-20.18 for motor stators equipped with sealed insulation systems.

8. LIMITS OF SUPPLY

The responsibility of the manufacturer of the motor covers the complete machines in proper working order. Unless otherwise specified in the provisions of the specification, supply of a motor is limited to :

- 1) Terminal boxes.
- 2) Electric power cable with the length proper for column height of tank including earthing cable.
- 3) Pressure gauge for N2 sealed piping before terminal box.
- 4) CT for Self-balancing protection 87 relay, above 1000kW motor

9. MANUFACTURER GUARANTEE

The following characteristics are in the scope of guarantee of the manufacturer:

- 1) Power
- 2) Torque
- 3) Efficiency
- 4) Power factor
- 5) Speed
- 6) Starting current
- 7) Noise level

8) Vibration limit