垂直缆进度与老化方案

汇报人：刘飞

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制作了承力缆样品

- 外径和刚性是否满足布放要求?
- 承力缆整体性
- 抱箍和支撑杆夹持设计是否需优化?

有待试验验证

进一步调研了变压器模块老化试验

电应力老化参考汽车行业的老化方法，和寿命计算方式，
如下图

Step 2 ➡ Test Plan

原则：以产品在实际应用环境所面临的使用条件而拟定的，而非以单一测试标准/条件来适用所有产品。

- 第一步：为制定该组件被设计/生产的目的，我们称之为Mission Profile

Service Lifetime	Mileage	Engine On Time	Engine Off Time	Non-OP Time	Engine On/Off Cycles
15 years =131,400Hrs	600,000km	12,000Hrs	3,000Hrs	116,400Hrs	54,000Hrs

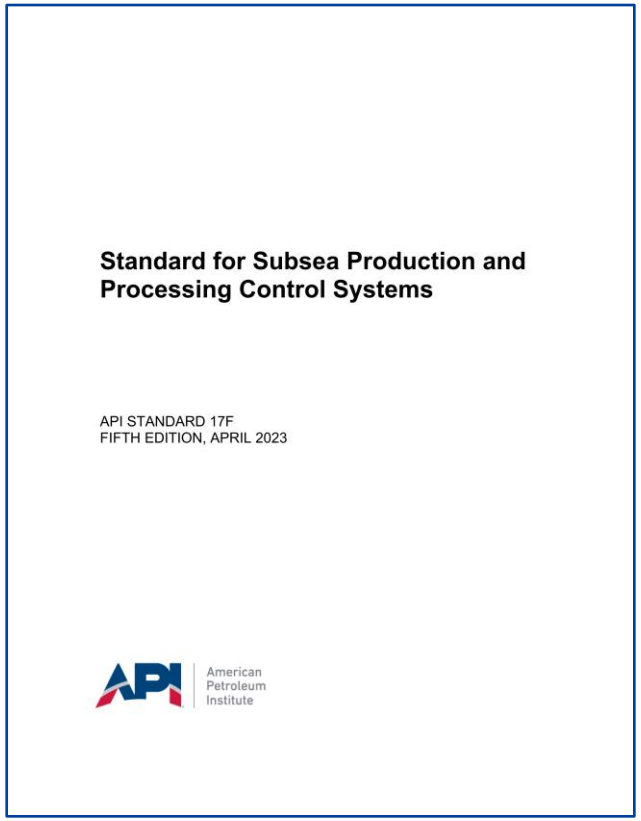
- 第二步：利用加速模型计算测试持续时间，若不适用，建立其他失效模式

Loading	Mission Profile Input	Stress Test	Stress Conditions	Acceleration Model (all temperatures in K, not in °C)	Model Parameters	Calculated Test Duration	Q100 Test Duration
Operation	t_u = 12,000 hr (average operating use time over 15 yr) T_u = 87°C (average junction temperature in use environment)	High Temperature Operating Life (HTOL)	T_t = 125°C (junction temperature in test environment)	Arrhenius $A_f = \exp\left[\frac{E_a}{k_B}\bullet\left(\frac{1}{T_u}-\frac{1}{T_t}\right)\right]$ Also applicable for High Temperature Storage Life (HTSL) and NVM Endurance, Data Retention Bake, & Operational Life (EDR)	E_a = 0.7 eV (activation energy: 0.7 eV is a typical value, actual values depend on failure mechanism and range from ~0.2 to 1.4 eV) k_B = 8.61733 x 10^{-5} eV/K (Boltzmann's Constant)	t_t = 1393 hr (test time) $t_t = \frac{t_u}{A_f}$	1000 hr

环境老化试验

序号	试验名称	引用标准	试验方法简述
1	冲击试验	API 17F-9.2.3.3.1	应沿三个相互垂直的轴在六个方向上分别施加四次冲击，冲击等级为30g，11ms半正弦
2	温度试验	API 17F-9.2.3.3.2	1、高温工作：现在40℃环境下浸泡48小时； 2、温度循环：以5℃/min升温至40℃，保持至少30min，在以5℃/min降温40℃，保持至少30min，循环至少10次。
3	振动试验	API 17F-9.2.3.3.3	以25 Hz到1000 Hz，加速度为5g的强度进行三轴方向振动试验
4	外部静水压力试验	API 17F-9.2.3.3.5	1、水压循环：45MPa，3次循环 2、水压试验：45MPa，保压6h
5	EMC测试	API 17F-9.2.3.3.6	根据IEC 61000-6-2所规定的静电放电： ±4kV（充电电压）接触式放电 ±8kV（充电电压）空气放电

参照标准API 17F



美国石油协会标准

9.2.3 Qualification Testing of Subsea Electrical and Optical Equipment

9.2.3.1 General

The qualification tests shall ensure that:

— the equipment is robust and suitable for the environment to which it is exposed during transportation, handling, installation, and operation;

— the exposure to the environmental stress screening (ESS) test procedure does not cause any damage to or degradation of the equipment's functionality.

The qualification tests shall be applied as follows:

— printed circuit boards and subassemblies shall be qualified to Q1 (see 9.2.3.3);

— electronic modules shall be qualified to Q2 (see 9.2.3.3);

— heavy equipment that cannot practically be tested according to Q2 and that comprises one or more circuit boards individually mounted within the design shall be qualified for handling and transportation in accordance with relevant transportation standards and operational requirements. The printed circuit boards shall be qualified to Q1.

Highly accelerated life testing (HALT) should be applied to ensure reliability and robustness of PCBA design.

9.2.3.3.1 Shock Tests

Four shocks shall be applied in each of six directions along three mutually perpendicular axes. The axes shall be selected to maximize the probability of detecting faults in the design.

For printed circuit boards or equipment containing printed circuit boards, one of the axes shall be perpendicular to the plane of the board or the majority of the boards, respectively. If, in normal service, shock absorbers or vibration dampers are part of the mounting, they shall be part of the mounting in the shock tests, as well. The shock level shall be as follows:

— Q1: 30 *g* acceleration, 11 ms half sine;

— Q2: 10 *g* acceleration, 11 ms half sine.

After the shock tests, no significant damage or distortion shall have occurred, and the EUT shall pass a full functional test.

9.2.3.3.2 Temperature Tests

With electrical power applied and under full load, the EUT shall be temperature soaked for 48 hours at the high design temperature.

If the EUT design is using the external housing as part of the conducted cooling system, the test fixture shall represent the actual design.

Components that are not designed to operate permanently under full load (e.g. power electronic components) shall be tested under intermittent or reduced load according to a specified load profile.

The same procedure shall be repeated for the low design temperature.

During the above temperature tests, reduced accuracy of measurement functions of the EUT may be tolerated. However, such functions should perform as specified at the normal operating temperature, as defined in Table 1.

Power off/on tests shall be performed at the start and end of each temperature soak to ensure that the EUT will power up at the high and low design temperatures. To reach thermal equalization with the climatic chamber, it is required to power off the EUT for an appropriate time before each off/on test (e.g. 1 hour).

The temperature tests shall be performed open frame with forced circulation of air or another heating medium if it is more appropriate to the application. To reduce the risk of condensation, it is acceptable to purge the air with nitrogen.

Following the soak tests, temperature cycle testing shall be performed.

A minimum of 10 thermal cycles shall be applied. The temperature limits for the temperature cycling shall be the maximum and minimum design temperatures as defined in Table 1. If faults resulting from flaws in workmanship are detected during thermal cycling, the flaws shall be repaired according to approved methods, and the sequence shall be started over. Design-related malfunctions shall be investigated and may require product redesign.

Ten thermal cycles alone are considered insufficient for the qualification test. Theoretical analysis or further temperature testing (e.g. accelerated life testing or quantitative life testing) shall be performed to ensure that the exposure to the ESS temperature cycling and burn-in do not cause any damage to or significant degradation of the equipment.

Each thermal cycle shall be performed as follows.

a) Increase to high design temperature at a minimum 5 °C/min (9 °F/min).

b) Keep at this temperature for a minimum of 30 minutes (or the duration for electronics to stabilize at design temperature).

c) Decrease to low design temperature at a minimum 5 °C/min (9 °F/min).

d) Keep at this temperature for a minimum of 30 minutes (or the duration for electronics to stabilize at design temperature).

9.2.3.3.3 Vibration Tests

The EUT shall be mounted on the test table using a similar fastening method as in normal service.

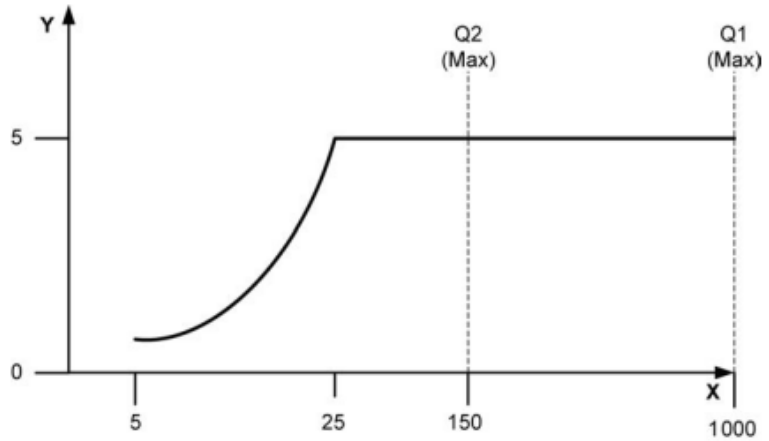
The vibration feedback sensor(s) (control sensor[s]) measuring the vibration test equipment excitation level shall be fixed to the test fixture. Sensors mounted on the EUT shall be used for monitoring purposes only, not for control.

The following excitation shall be applied to three mutually perpendicular axes. The axes shall be selected to maximize the probability of detecting faults in the design. For printed circuit boards or equipment containing printed circuit boards, one of the axes shall be perpendicular to the plane of the board or the majority of the boards, respectively. The excitation level shall be as follows (as illustrated in Figure 5):

— Q1 and Q2: 5 Hz to 25 Hz with ±2 mm displacement;

— Q1: 25 Hz to 1000 Hz with 5 *g* acceleration;

— Q2: 25 Hz to 150 Hz with 5 *g* acceleration.



Key

X frequency in hertz on a logarithmic scale

Y acceleration, expressed in *g*

Figure 5—Acceleration, *g*, over Mechanical Vibration Frequency

9.2.3.3.4 Electrical Power System and Communication System Sensitivity Tests

The qualification tests shall ensure that:

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— electrical communication system components demonstrate acceptable performance capability throughout the full specified range(s) of input parameters (sensitivity testing) and noise immunity;

— electrical power system components demonstrate acceptable performance capability throughout the full specified range(s) of input parameters (sensitivity testing); this shall include extended-life testing, if relevant.

9.2.3.3.5 External Hydrostatic Tests of Electronic Enclosures

External hydrostatic tests shall be performed on 1atm electrical enclosure at 1.1 times the design ambient pressure. The external hydrostatic test pressure shall be maintained for a minimum of 6 hours, in addition to performing three pressure cycles without impact on functionality. The hold period may be part of one of the pressure cycles. One pressure cycle is from ambient to test pressure and back to ambient pressure. Acceptance criteria shall be no water ingress and no impact on functionality.

9.2.3.3.6 EMC Tests

The subsea system is required to be compatible with the subsea EM environment. None of the electrical and electronic elements shall interfere with the functional or safety-related operation of any other element, whether it is part of the same system or an unrelated system. All elements shall be immune to all predicted EM phenomena to a level determined by the functional or safety-related requirements of the system.

As guidance for subsea equipment, no subsea equipment should generate EM disturbances so that other subsea equipment is prevented from operating as intended (both when deployed subsea and during surface-based testing). In the presence of disturbances, whether they are locally generated or conducted from a remote location, subsea equipment should have a level of immunity that allows it to operate as intended without unacceptable degradation of performance. Performance should meet Criterion A in the presence of continuous phenomena and Criterion B in the presence of transient phenomena.

For subsea equipment, each application needs to be considered with regard to its installed environment.

The subsea environment does not support radiated propagation for high-frequency EM phenomena, so if the generic industrial product standard IEC 61000-6-2 is used as guidance, only the conducted phenomena test requirements should be considered.

The EMC test matrix (see Table 5) provides an appropriate level of confidence for subsea equipment. The test standards cited refer only to “power ports” and “signal ports.” For the purposes of applying these test standards to the test specifications listed in Table 5, any port that is not a power port shall be considered o be a signal port.

Table 5—EMC Test Matrix

Test Number	Basic Test Standard	Test Specification	Performance Criteria
1	IEC 61000-4-2	Electrostatic discharge according to IEC 61000-6-2: — ±4 kV (charge voltage) contact discharge — ±8 kV (charge voltage) air discharge	B
2	IEC 61000-4-4	Fast transients according to IEC 61000-6-2: 5/50 Tr/Th ns, 5 kHz repetition frequency — ±1 kV on signal ports — ±2 kV on input and output power ports	B
3	IEC 61000-4-6	Radio-frequency common mode, power, and signal port: — 0.15 MHz–80 MHz — 3 V	A
4	CISPR 32 (EN 55032)	Conducted emission on power ports and signal ports/communication ports: — 0.15 MHz–30 MHz	According to class A
5	IEC 61000-4-5	Surge according to IEC 61000-6-2 power and signal port	B
6	IEC 61000-4-11	Voltage dip, variations, and short interruptions immunity (power ports) (AC-powered systems)	B
7	IEC 61000-4-13	Power harmonic immunity (power ports) (AC-powered systems)	B

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