



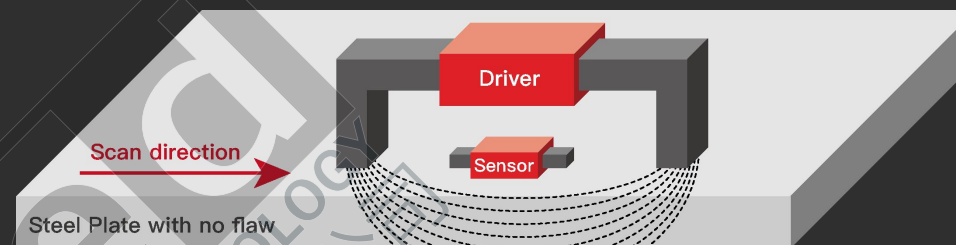
LFET – Corrosion Detection

Low Frequency Electromagnet Technology
适用于腐蚀检测的低频电磁检测技术

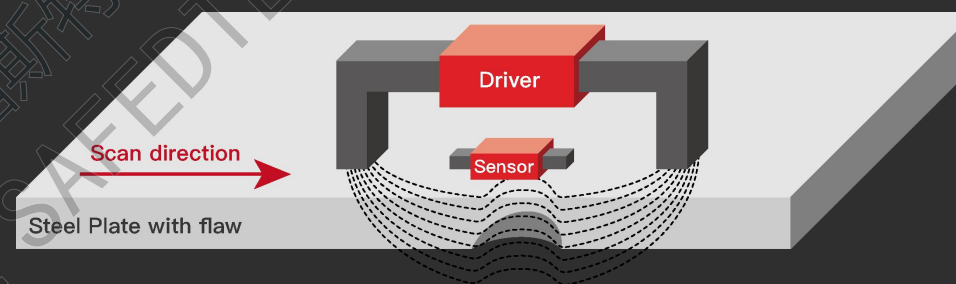
Theory of the LFET probes

LFET 扫查头技术原理

低频电磁检测技术 LFET (Low Frequency Electromagnetic Technique) 使用离散的激励和接收传感器线圈，激励线圈在较低的频率 ($\leq 10\text{Hz}$) 下激发产生一个交变电磁场，并穿透被测材料，从其一侧传导到另一侧。在没有壁厚减薄和缺陷的地方，电磁场产生一定信号强度衰减，如图1所示；当探头移动到壁厚减薄和缺陷的地方时，可以检测到一个较强的电磁场信号，如图2所示。



- With no flaw, sensor sees uniform magnetic field as probe sweeps across the plate.
在无缺陷钢板上，探头扫过时传感器接收到规则的磁场



- With flaw, sensor sees distorted magnetic field near the flaw as probe sweeps across the plate.
在有缺陷的钢板上，探头扫过时传感器接收到缺陷附近被扰乱磁场

Applications of LFET

LFET 适用场景



■ 适用场景

- 密排管道
- 水冷壁管
- 异型管件
- 小管径管道



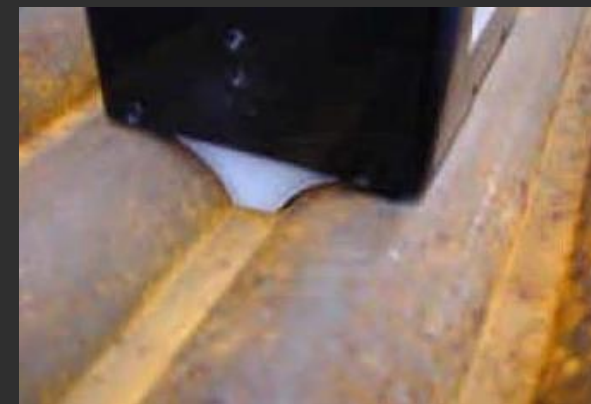
▲ 弯管扫查器



▲ 小区域扫查器



▲ 小管径扫查器



▲ 肋片扫查器

Applications of LFET

LFET 适用场景

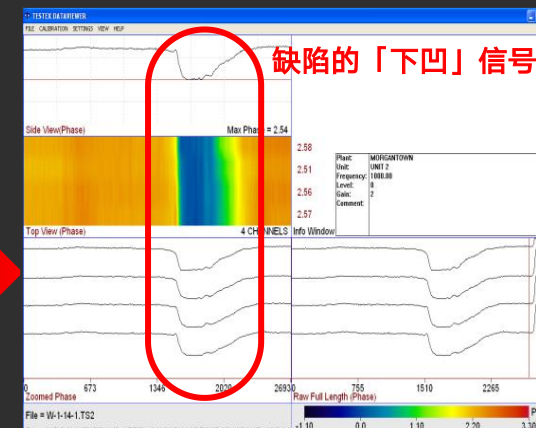


堵管检测

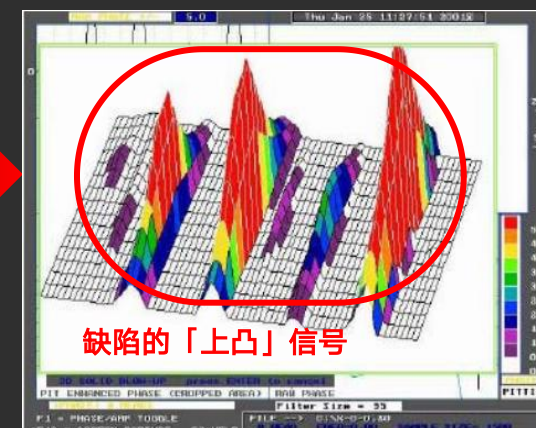
铁磁性垢物, Fe_2O_3 等



低点沉积



低点腐蚀



原理: 铁磁性垢物, 如 Fe_2O_3 、 Fe_3O_4 、 NiO 等, 具有导磁性, 增加局部磁导率 (降低磁阻), 这个特征正好与缺陷诱发的磁信号变化相反

Applications of LFET

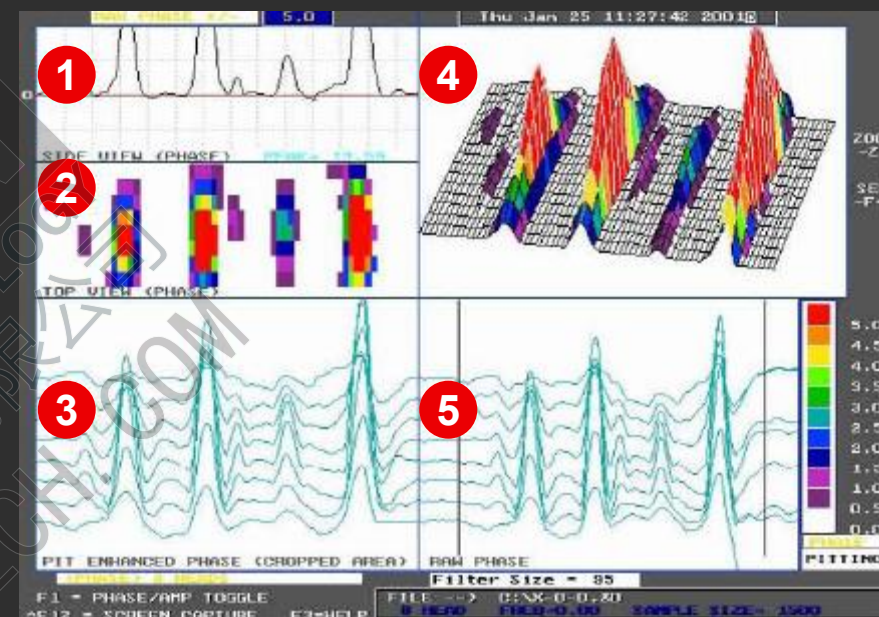
LFET 适用场景



▲ 锅炉内的水冷壁管现场



▲ 扫查器检测



▲ Full screen view of corrosion displayed by software
软件显示的腐蚀全屏视图

- ① Lateral View
侧视图
- ② Vertical View (C-Scan)
俯视图 (C-scan)
- ③ 8-Channel Data
Processing Window
8通道数据处理窗口
- ④ 3D View
3D视图
- ⑤ Raw Data Window
原始数据窗口

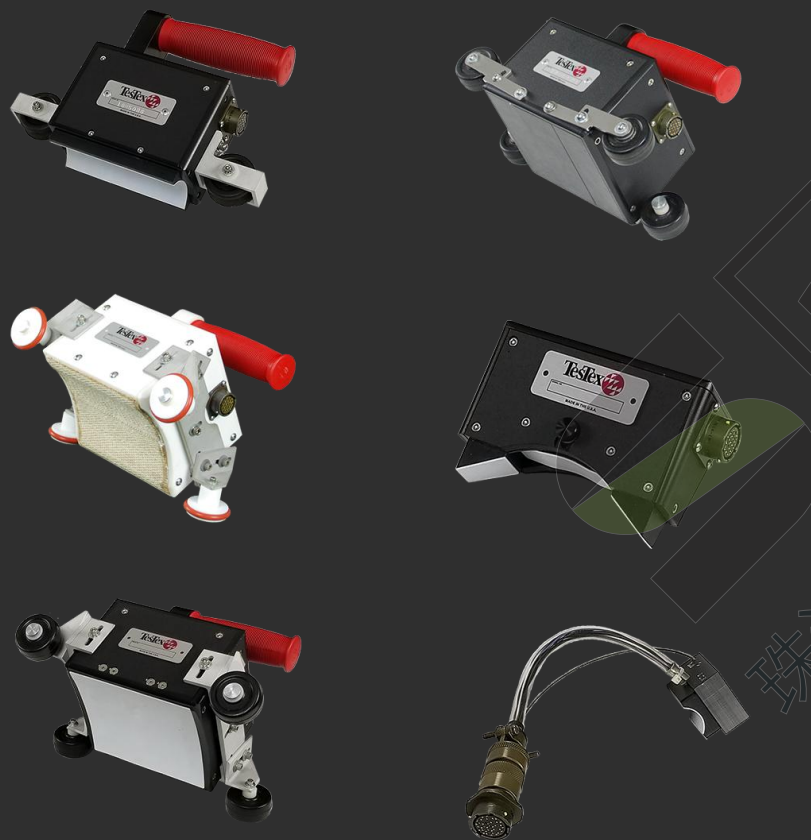
Scanners of LFET

LFET 系列扫查器



技术参数

最大可测金属厚度	19 mm
一次扫查角度	170° (DN ≤ 100 mm)
阵列通道数量	8 / 16通道
可测材料	铁磁性或顺磁性材料
可测缺陷	坑蚀、减薄、裂纹
可测内容	缺陷定位、缺陷定量 (长宽)
最大扫描速度	50 ~ 75 mm/s
抗干扰能力	油漆、镀层、锈对检测无影响
检测数据处理能力	A扫、B扫、C扫
堵管状态参数	堵塞物增量 (堵管截面积5%及以上)、 垢的干湿性、堵塞物起始位置



LFET Water Wall Inspecting System

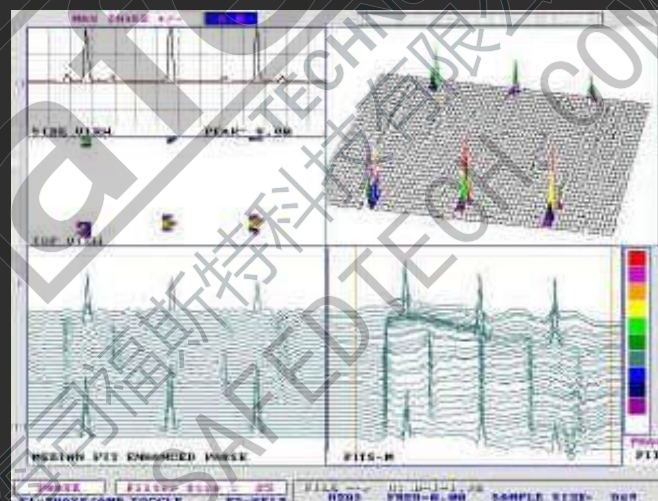
LFET 水冷壁检查系统



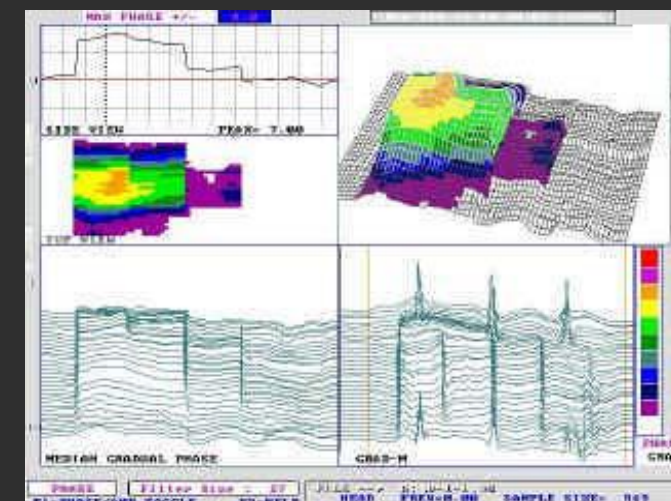
Electromagnet Imaging Technology 电磁成像技术

Defects have a volumetric shape, especially the thinning of wall thickness, whose changes must be described by three-dimensional parameters. Low-frequency electromagnetic detection has developed phase resolution technology, and various methods such as phase analysis, frequency analysis, and amplitude identification are used in signal analysis and processing, which can analyze and process the amplitude and phase changes of electromagnetic signals.

缺陷是有体积形状的，尤其是壁厚的减薄必须要用三维参量描述其变化。低频电磁检测发展了相位分辨技术，在信号的分析 and 处理中采用了相位分析、频率分析和幅值鉴别等多种方法，能够对电磁信号的幅度、相位变化进行分析处理。



▲ 点蚀
Pit



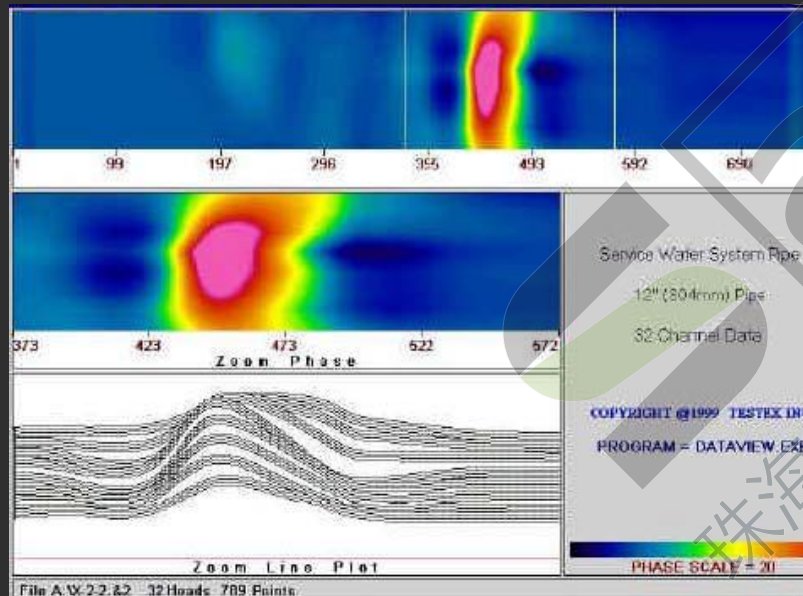
▲ 壁厚减薄
Wall loss

LFET Water Wall Inspecting System



LFET 水冷壁检查系统

Electromagnet Imaging Technology 电磁成像技术



C-scan

Meanwhile, electromagnetic three-dimensional imaging technology has been developed, and corresponding information processing technology and display methods have been developed based on the defect generation mechanism, thereby obtaining more reliable defect information, which can directly identify wall thickness thinning and pitting corrosion. In addition, its unique 3D rotation display technology can intuitively find the location of defects.

同时研发出了电磁三维成像技术，根据缺陷产生机理研究出相应信息处理技术和显示手段，从而得出更可靠的缺陷信息，可以直接分辨出壁厚减薄、点蚀。另外其独有的3D旋转显示技术，可以直观地发现缺陷的位置。

LFET Water Wall Inspecting System

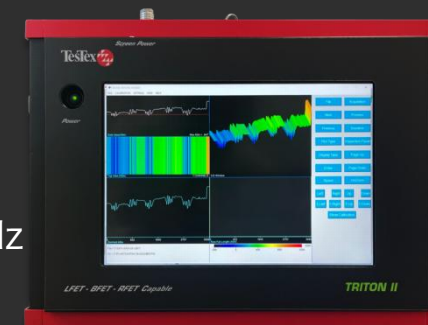


LFET 水冷壁检查系统



■ 显示控制一体机 Triton II

重量 Weight	4.9 kg
尺寸 Size	353 mm × 274 mm × 122 mm
通道数 Channels	8通道
供电电源 Power	110/220VAC (可调节) 50/60Hz
操作系统 OS	Windows 10
储存容量 Storage	128 GB



■ 扫描器 Scanner

重量 Weight	0.14 - 0.7 kg (根据应用变化)
工作频率 Frequency	3 Hz - 30k Hz
最大穿透能力	19 mm
扫描宽度	在外径 100 mm 下可达170度
探头/通道数	8/8 或 16/8



- ✓ 可以检测出≤6mm的金属钢管上30%深度直径3mm的点蚀

LFET Water Wall Inspecting System

LFET 水冷壁检查系统

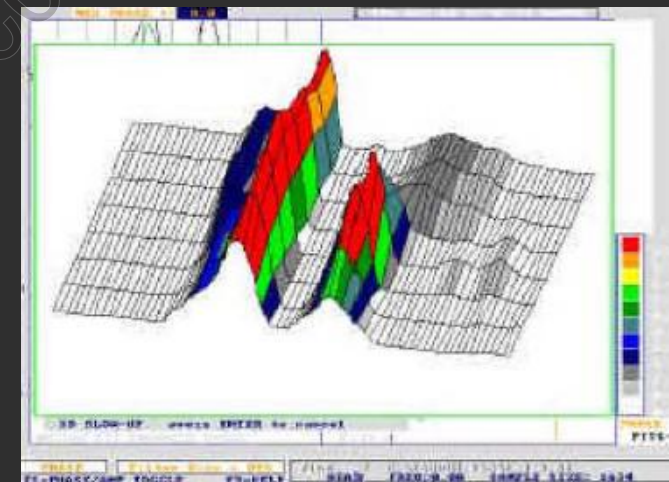


Typical Defects Examples 典型缺陷案例

- LFET技术可以检测腐蚀性和磷酸性雀斑、氢蚀、氧化点蚀、裂纹（包括不锈钢上的应力腐蚀性裂纹）、流动气体/高/低NO_x 和SO_x 侵蚀、虫孔和制造过程缺陷。



▲ 锅炉钢管氢蚀的剖面图



▲ 严重氢蚀的波形图

LFET Water Wall Inspecting System



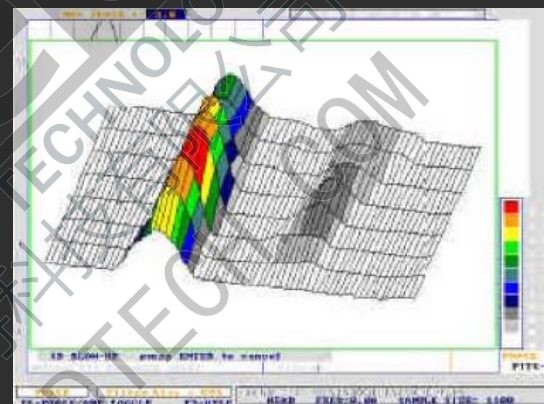
LFET 水冷壁检查系统

Typical Defects Examples 典型缺陷案例

1



Two pits on the boiler threaded steel pipe
螺纹锅炉钢管上的两个点蚀

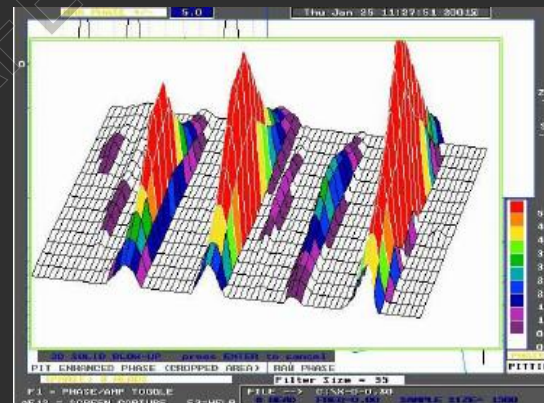


The waveform of the two pits
两个点蚀的波形图

2



Corrosive gouges in the inner wall of boiler steel tube
锅炉钢管内壁的腐蚀性凿坑



The waveform of the corrosive gouges
内壁腐蚀性凿坑的波形图