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PREMATURE DEGRADATION AND FAILURE OF STEAM – METHANE REFORMER HEATER SYSTEM COMPONENTS

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ABSTRACT

Bulk hydrogen production in a petroleum refinery by steam–methane reforming utilizes high temperatures, moderate pressures and catalyst – filled tubes which generate high tube temperatures of up to 1,690 °F [920 °C] imposing relatively harsh performance demands on system components which are not usually encountered in other refinery or petrochemical plant equipment.

Creep rupture and high temperature cycling place a severe service duty on the catalyst tubes, tube outlet pigtails, the sub-header train and the downstream steam generator leading to ruptured pigtails, cracking in sub-headers and break up of the ceramic tube sheet ferrules at the steam generator inlet tubesheet.

Although the industry has developed specific fit-for-purpose design practice standards augmented with detailed technical reports, reliability issues persist and regularly force premature shutdown of the reformer heater and downstream heat recovery equipment.

Among these practices are API Standard 530 and API TR 942-A. API 530 assists designers in the selection of materials and determination of pressure design thickness of heater tubes while API TR 942-A attempts to reconcile the contradictory industry experience where some operators have little or no problems while others suffer premature degradation and cracking of outlet pigtails and manifold components.

A reconciliation between application of industry design practices and equipment performance is presented in this paper to determine whether systemic issues contribute to the apparent situation; and, recommendations are made for pressure component design and material selection for steam-methane reformers.

NOMENCLATURE

D	damage fraction
D_o	tube outside diameter
E	modulus of elasticity
K	the section factor for the cross section
P_L	primary membrane stress
P_b	bending stress
S_{Ravg}	average stress to cause rupture at the end of 100,000 hours
S_{Rmin}	minimum stress to cause rupture at the end of 100,000 hours
S_C	average stress to produce a creep rate of 1% per 100,000 hours
$S_{Rmin,\,t}$	minimum stress to cause rupture for a specified design life; data being provided for 20,000, 40,000, 60,000 and 100,000 hour rupture allowable stresses. Usually, t = 100,000 hours
S_t	temperature, time dependent stress limit; for the reformer, creep rupture stress at 100,000hours
T	temperature
ΔT	temperature difference
Y	time in years
YS	yield strength
a	thermal diffusivity
m	rate of temperature increase at outer surface
p	internal pressure
p_r	design pressure
r	radius at an intermediate point
r_i	inside radius of tube / cylinder
r_o	outside radius of tube / cylinder
t_i	time spent at condition i
t_{ri}	time to rupture at condition i
α	coefficient of expansion
δ	wall thickness calculated per API 530
ν	Poisson's ratio