Methane to Markets

Recovering Methane Emissions from Tanks and Compressors
回收储罐和压缩机排放的甲烷

Methane to Markets : International Workshop on Methane Emission Reduction Technologies in the Chinese Oil and Natural Gas Industry

Qingdao, China（中国，青岛）

17-18 April, 2008（2008年4月17-18日）

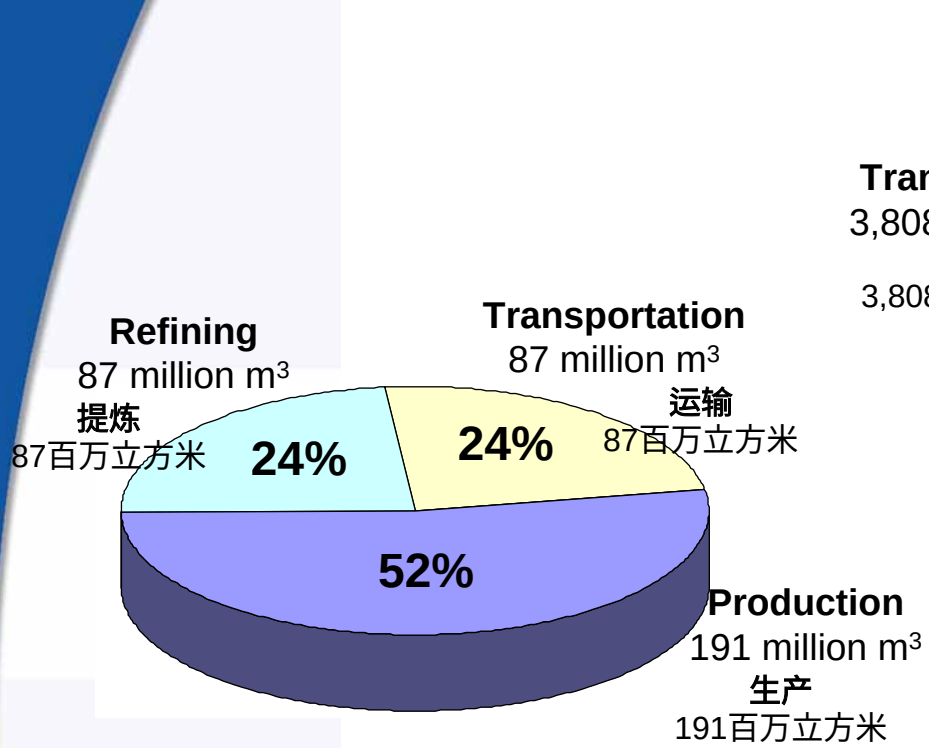
Agenda
汇报提纲

- China Oil & Gas Methane Emissions
  中国油气系统的排放
- Tanks / Compressors
  储罐/压缩机
  - Methane Losses
    甲烷损失
  - Methane Recovery
    甲烷回收
  - Is Recovery Profitable?
    回收效益？
  - Industry Experience
    工业经验

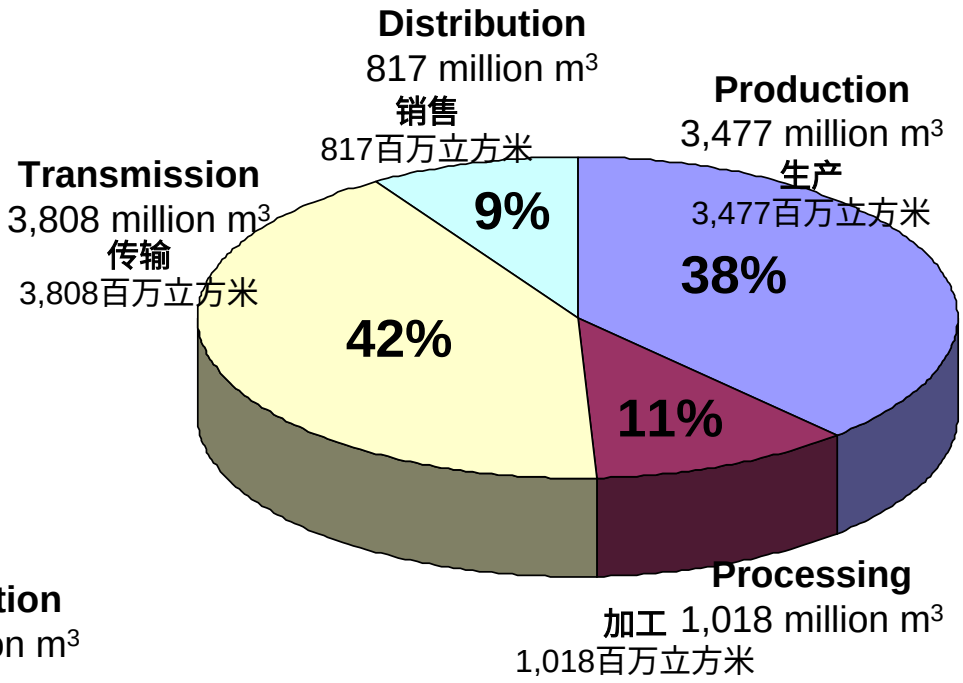
Source: PEMEX

Source: Petroleos de Venezuela S.A

China Oil and Gas Methane Emissions in 2005
2005年中国油气系统的甲烷排放



Petroleum Systems Emissions
石油系统泄漏



Natural Gas Systems Emissions
天然气系统泄漏

m^3 = cubic meters

Sources: 1 – EPA. *Global Anthropogenic Emissions of Non-CO2 Greenhouse Gases 1990-2020* (EPA Report 430-R-06-003). China emissions.
2 – Technology Drives Methane Emissions Down, Profits Up, Oil and Gas Journal, August 13, 2007
Note: It is assumed that all natural gas produced, goes through gas processing.

Estimated Methane Losses from China Production
中国生产过程中的甲烷损失

- **Storage tank venting may be responsible for 4% of methane emissions in the natural gas and oil production sectors**

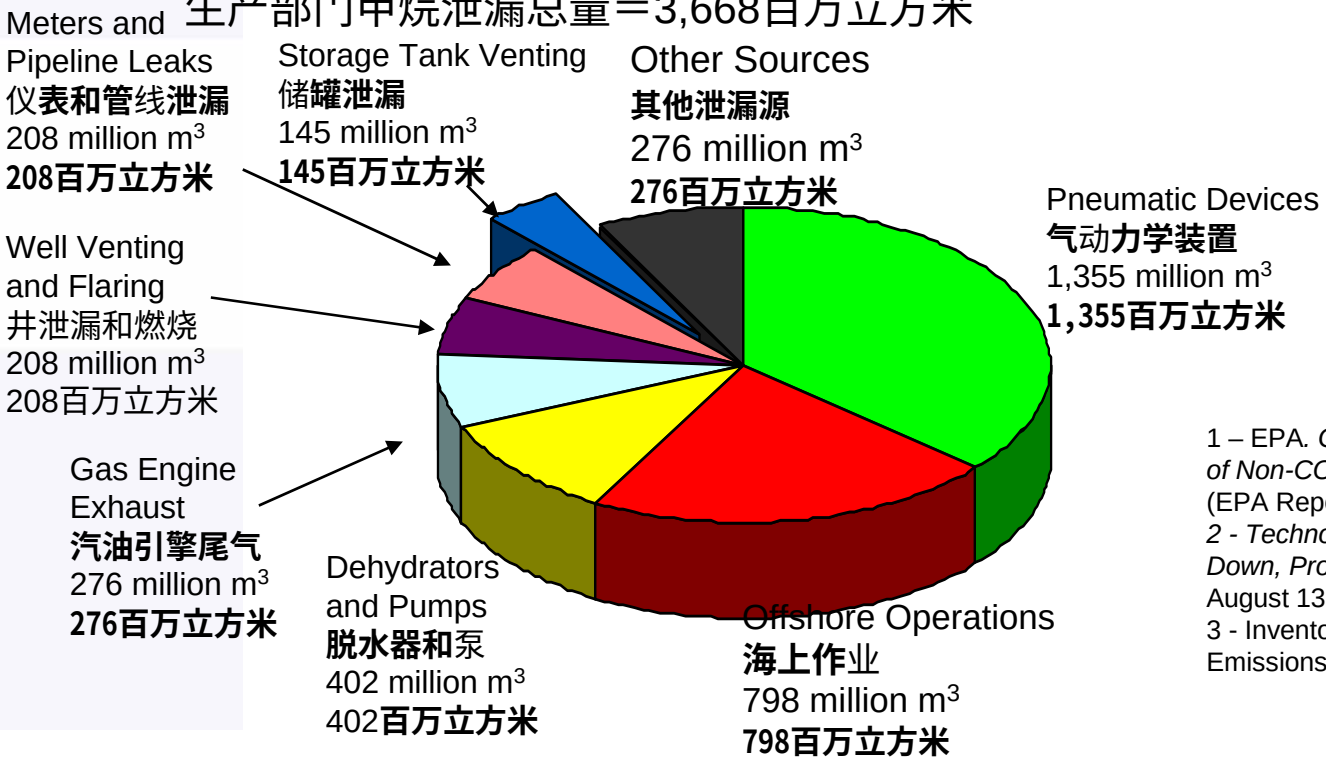
  储罐泄漏甲烷量占天然气和石油生产部门甲烷排放总量的4%

  - Anecdotal evidence suggest it could be significantly more

    轶事证据表明储罐泄漏甲烷量可能更多

  - Total emissions from Production Sectors = 3,668 million m^3

    生产部门甲烷泄漏总量＝3,668百万立方米



1 – EPA. *Global Anthropogenic Emissions of Non-CO2 Greenhouse Gases 1990-2020* (EPA Report 430-R-06-003)
2 - Technology Drives Methane Emissions Down, Profits Up, Oil and Gas Journal, August 13, 2007
3 - Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005

Methane Losses from Storage Tanks
储罐的甲烷损失

- **A storage tank battery can vent 140 to 2,720 thousand m³ of natural gas and light hydrocarbon vapors to the atmosphere each year**

  储罐电池每年大概向大气中排放天然气和轻碳水化合物蒸汽14～272万立方米。

  - Vapor losses are primarily a function of oil throughput, gravity, and gas-oil separator pressure

    蒸汽损失主要是生产量、重力和油气分离器压力的函数。

- **Flash losses** 闪蒸损失
  - Due to pressure drop from upstream equipment

    原因是来自上游装置压降
- **Working losses** 操作损失
  - Due to level change

    原因是液面变化
- **Standing losses** 储存损失
  - Due to atmospheric temperature and pressure changes

    大气温度和压力变化

Source: Hy-bon Engineering

Methane Recovery: Vapor Recovery
甲烷回收：蒸汽回收

- **Vapor recovery can capture up to 95% of hydrocarbon vapors from tanks**
  蒸汽回收可以捕获储罐释放蒸汽量的95%
- **Recovered vapors have higher heat content than pipeline quality natural gas, adding value**
  回收蒸汽比管道天然气的热容量高，增加价值
- **Vapors have multiple uses** 蒸汽的用途
  - Re-inject into sales pipeline
    回注到销售管线中
  - Use as on-site fuel
    作为现场燃料
  - Send to processing plants for recovering valuable natural gas liquids
    为回收有价值的天然气液体将蒸汽传输到加工设备

Source: Petroleos de Venezuela S.A

Methane Recovery: Vapor Recovery
甲烷回收：蒸汽回收

- Technical document available in Chinese

中文技术资料

在原油储罐上安装蒸汽回收装置

INSTALLING VAPOR RECOVERY UNITS ON CRUDE OIL STORAGE TANKS

1 内容提要

美国目前大约有 573 000 个原油储罐。这些原油储罐用于短暂储存原油以稳定生产井和管线或卡车运输场所之间的流动。在原油储存期间，溶解在原油中的轻质烃——包括甲烷和其他挥发性有机组分（VOC）、天然气凝液（NGLs）、危险性空气污染物（HAP）和一些惰性气体——从原油中蒸发或“闪蒸”出来并聚集在液面和储罐顶部之间的空间中。当原油储罐中的液面发生波动时，这些蒸汽通常将被排放到空气中。

一种阻止这些轻质烃蒸汽发生泄漏并能产生显著经济效益的方法是在原油储罐上安装蒸汽回收装置（VRUs）。VRUs 是一种相对简单的系统，能从储罐中收集大约 95%的烃类蒸汽，这些蒸汽既可用于销售，也可就地作为燃料使用。目前，有 8 000～10 000 个 VRUs 安装在原油生产现场，每个 VRU 上平均连接 4 个原油储罐。

天然气 STAR 计划合作伙伴已经从回收和销售这些轻烃蒸汽中获得了巨大的经济效益，同时还极大地减少了甲烷气和 HAP 排放量。合作伙伴发现，当轻烃蒸汽量充足时，在一个或多个原油储罐上安装一个 VRU 每年可节省 260 060 美元，并且最快在 3 个月之内就能收回投资。本文介绍了合作伙伴应如何来确定在何时何地安装 VRUs 才能实现经济效益和环境效益的双丰收。

Types of Vapor Recovery Units
蒸汽回收装置类型

- Conventional vapor recovery units (VRUs)

  常规蒸汽回收装置

  – Use rotary or vane compressor to suck vapors out of atmospheric pressure storage tanks

    用旋转式或翻板式压缩机从大气压下的储罐中吸吮蒸汽

  – Scroll compressors are new to this market

    涡卷式压缩机是这个领域新装置

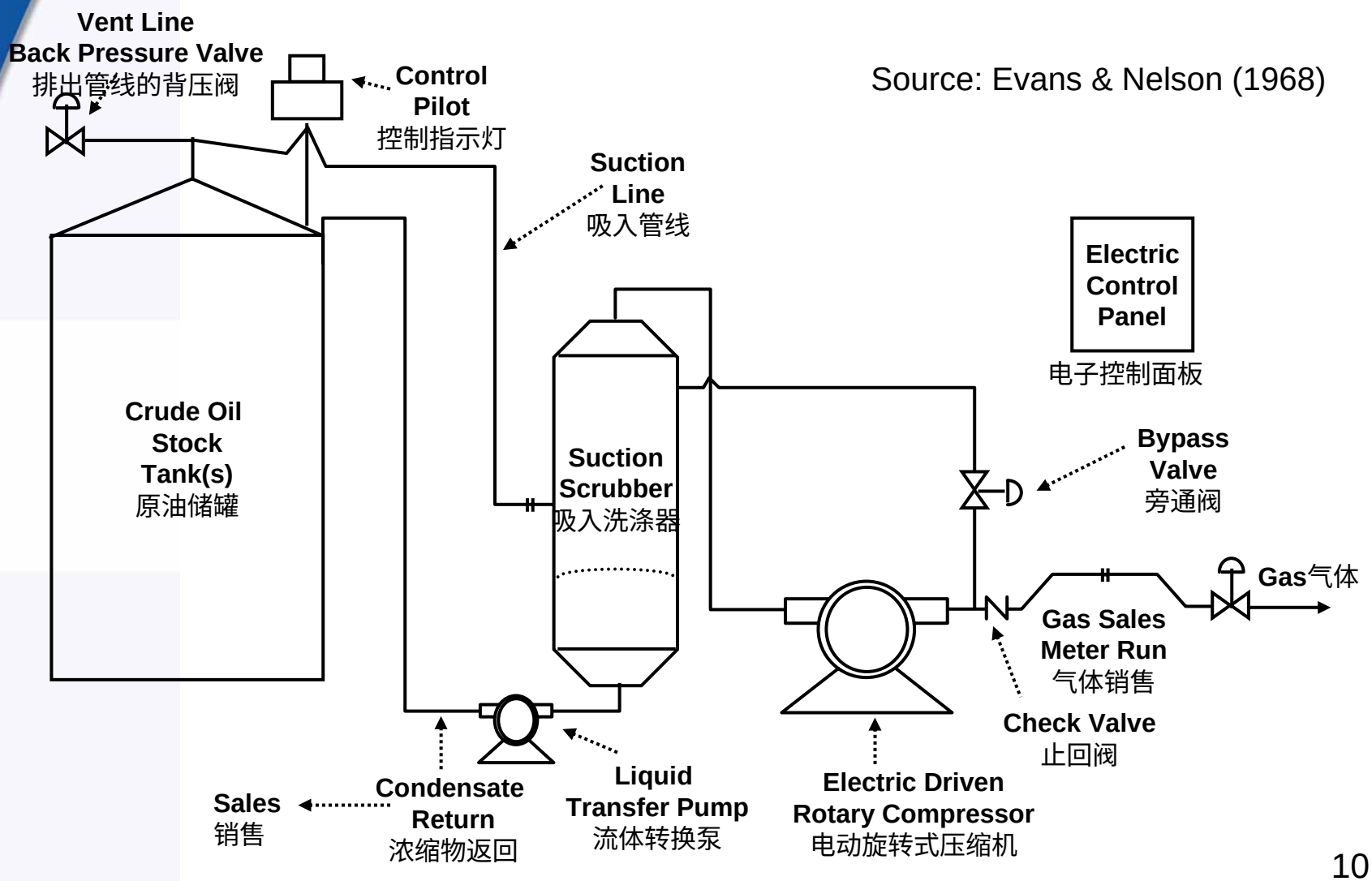
  – Require electrical power or engine driver

    需要有电源或发动机驱动

Types of Vapor Recovery Units
蒸汽回收装置类型

- Venturi ejector vapor recovery units (EVRU™) or Vapor Jet 文丘立喷射器蒸汽回收装置或蒸汽喷嘴
  - Use Venturi jet ejectors or EVRUs in place of rotary compressors
    用文丘里喷射器或常规蒸汽回收装置代替旋转式压缩机
  - Contain no moving parts
    装置中不含有可移动部分
  - EVRU™ requires a source of high pressure motive gas and intermediate pressure discharge system
    EVRU™需要一个高压推动气源和中间压力释放系统
  - Vapor Jet requires a high pressure water motive
    蒸汽喷嘴需要有高压水推动装置

Conventional Vapor Recovery Unit
常规蒸汽回收装置

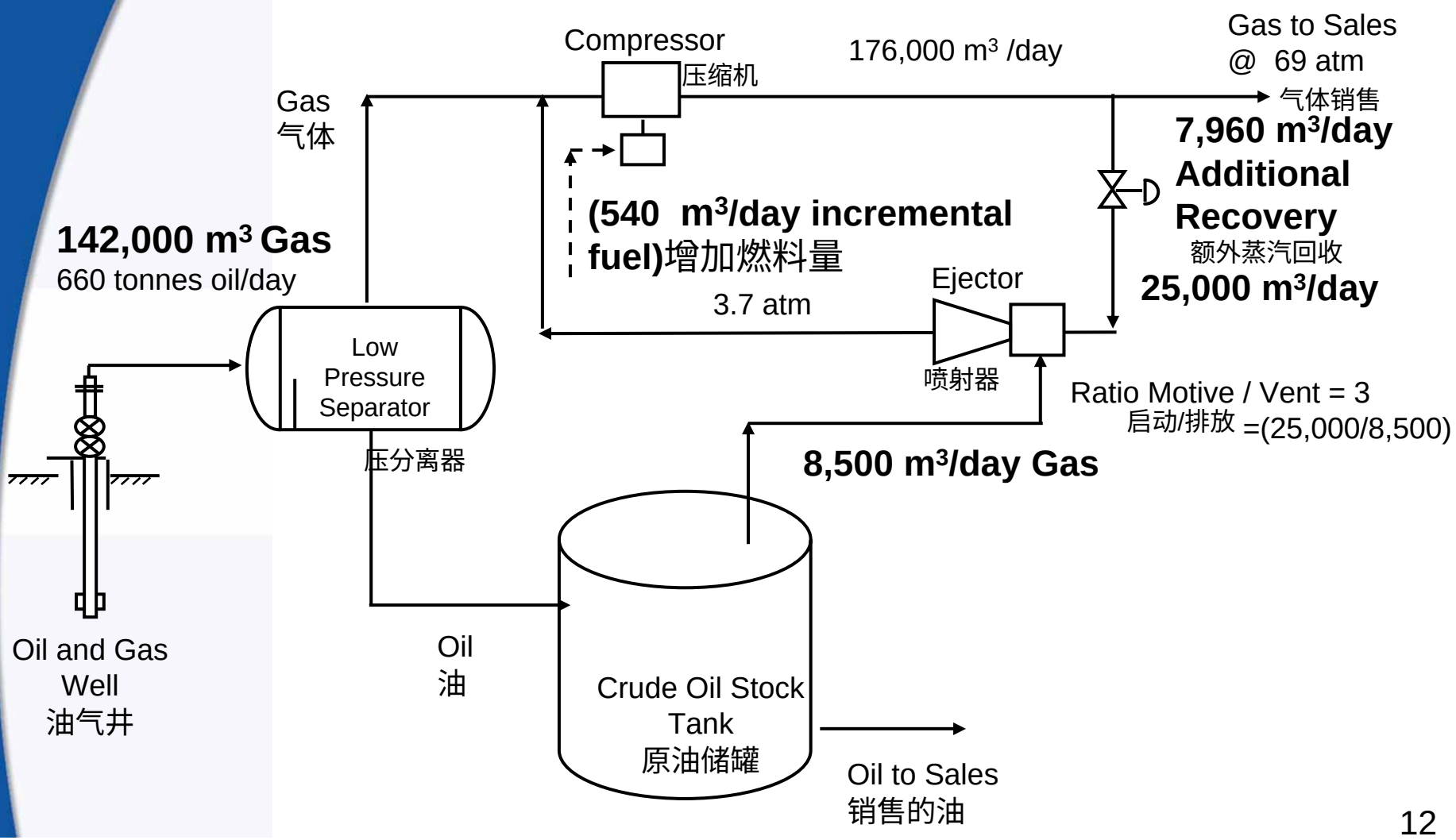


Source: Evans & Nelson (1968)

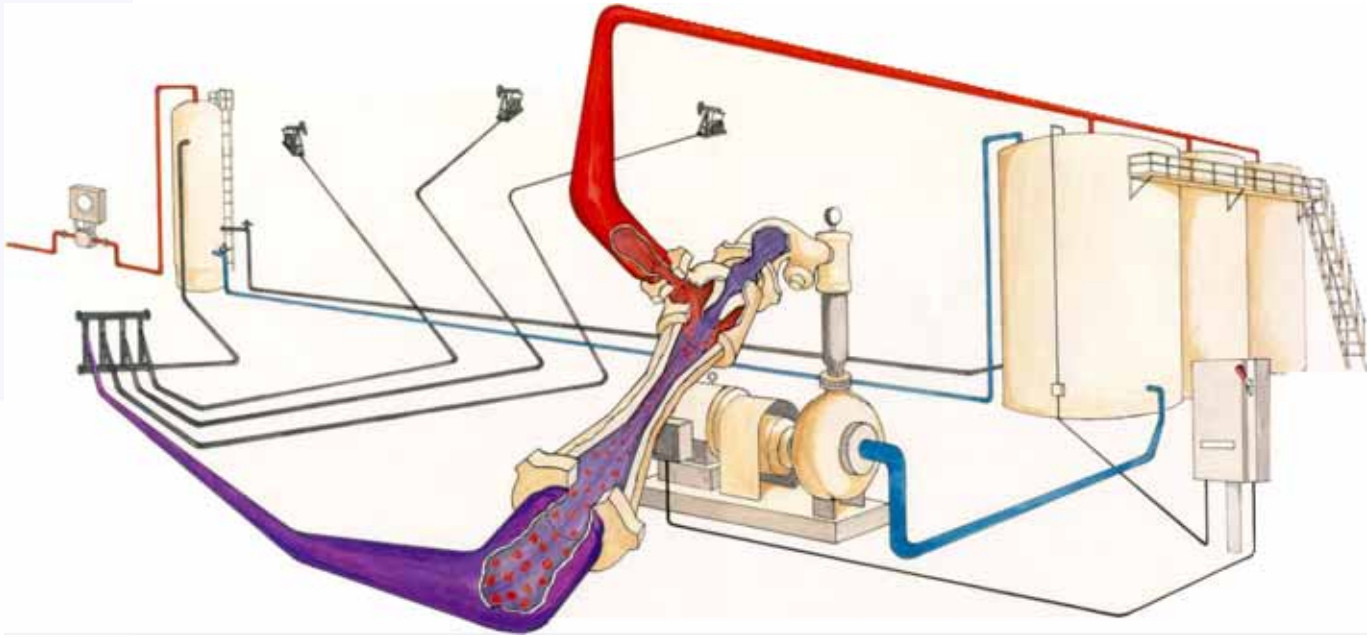
Vapor Recovery Installations
蒸汽回收装置安装

Source: Hy-Bon Engineering

Vapor Recovery with Ejector
带有喷射器的蒸汽回收装置



Vapor Jet System*
蒸汽喷嘴系统



- Utilizes produced water in closed loop system to effect gas gathering from tanks
  利用闭环系统中产生的水从储罐有效地收集蒸汽
- Small centrifugal pump forces water into Venturi jet, creating vacuum effect
  小型离心泵将水注入文丘里喷嘴，形成真空效应
- Limited to gas volumes of 2.2 thousand m^3/ day and discharge pressure of 3.7 atm
  蒸汽体积控制在2,200m^3/d，释放压力为3.7atm

*Patented by Hy-Bon Engineering

Criteria for Vapor Recovery Unit Locations
蒸汽回收装置安装准则

- Steady source and sufficient quantity of losses
  稳定泄漏源和损失量
  - Crude oil stock tank　原油储罐
  - Flash tank, heater/treater, water skimmer vents
    闪蒸罐，加热器/处理器，水撇油器排放
  - Gas pneumatic controllers and pumps　气动力学控制器和泵
  - Glycol dehydrator, well casingheads　乙二醇脱水器，井的套管头

Gas Outlet: Remote Site VRU Application Using Micro Turbine

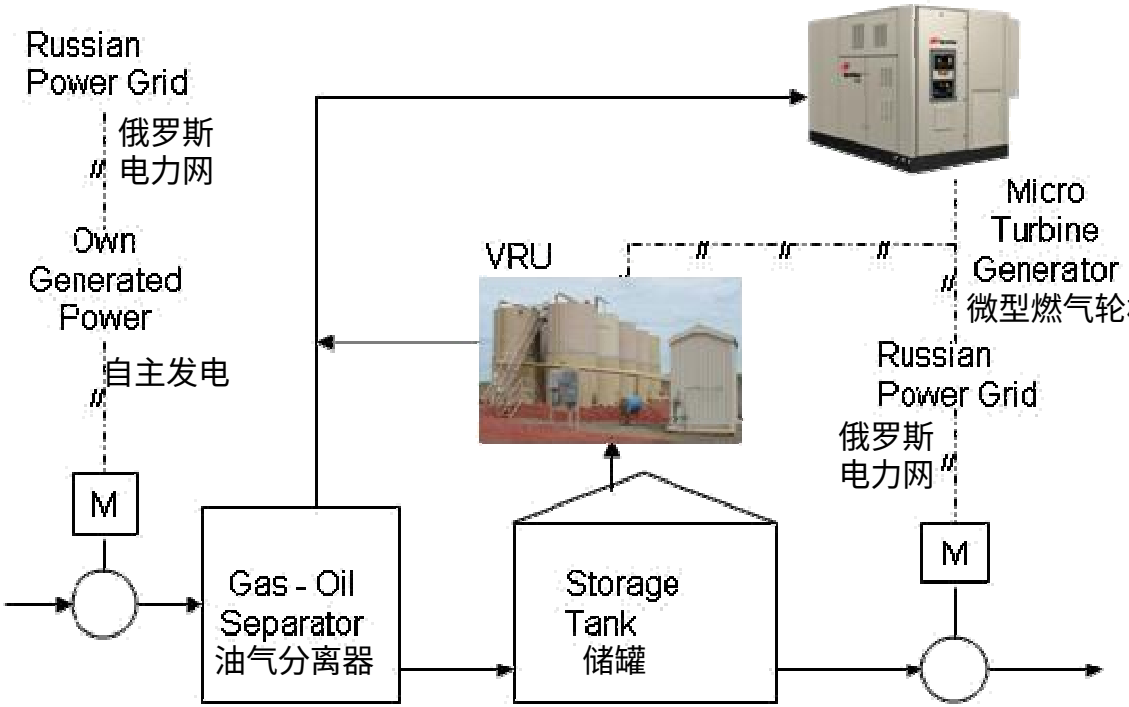
蒸汽出口：蒸汽回收装置远程现场应用－使用微型燃气轮机

- Vapors can be put to beneficial use at sites not connected to gas sales line

  在不将蒸汽连接到销售管线的现场，蒸汽也其他用途

  – Micro turbines generate power from varying qualities of gas

    微型燃气轮机通过气体质量变化发电



Source: TNK-BP Russian project diagram

Is Recovery Profitable?
蒸汽回收有效益吗？

- Value depends on heat content of gas and how it is used

  价值与蒸汽的热容量和用途有关

  - On-site fuel 现场燃料
    - Valued in terms of fuel that is replaced

      蒸汽价值依据其代替的燃料价值而定
  - Natural gas pipeline 天然气管线
    - Measured by the higher price for rich (higher heat content) gas

      富蒸汽（热容量高）的价格高
  - Gas processing plant 天然气加工装置
    - Measured by value of natural gas liquids and methane, which can be separated

      用被分离出的天然气液体和甲烷的价值测量

Is Recovery Profitable?
蒸汽回收有效益吗？

- Example: VRU recovering 2,800 m^3/day (100 thousand cubic feet) has:

  例：蒸汽回收装置每天回收蒸汽2800m^3（10万立方英尺）：

  - $55,524 installed cost

    安装费用55,524美元

  - $10,103/year operating and maintenance cost

    操作和维修费用10,103美元/年

Note: All costs and revenues are represented in U.S. economics
注意：所有费用和收益计算与美国经济一致
Total installed cost assumed to be 175% of unit cost
安装总费用认为是装置费用175%

Is Recovery Profitable?
蒸汽回收有效益吗？

- Calculate gas savings:

  计算蒸汽节省：

  – $2,800 m^3/day x 95% recovery x 50% capacity x 365 days/year x $0.25/$m^3$ = **$121,360/year**

  （2800m^3/天×95%回收×50%容量×365天/年）美元＝121,360美元/年

- Economics:

  经济效益：

  – 6 months payback

  6个月成本回收

  – 200% internal rate of return

  内部回收率200%

- Economics get more attractive for larger units

  回收装置越大，经济效益越有吸引力

Vapor Recovery Towers
蒸汽回收塔

- Vapor Recover Tower (VRT)

  蒸汽回收塔（VRT）

  – Add separation vessel that operates near atmospheric pressure between higher pressure equipment and tanks

    在高压设备和储罐之间增加分离容积，它在大气压附近运行

  – Compressor (VRU) captures gas from VRT under steady operating conditions

    在稳态运行条件下，压缩机（VRU）从蒸汽回收塔收集气体

Vapor Recovery Towers
蒸汽回收塔

– Oil/condensate gravity flows from VRT to storage tanks

油/凝析油在重力作用下从蒸汽回收塔流向储罐

- VRT insulates the VRU from gas surges with stock tank level changes

  蒸汽回收塔把随储罐液面变化涌出的气体与蒸汽回收装置分离

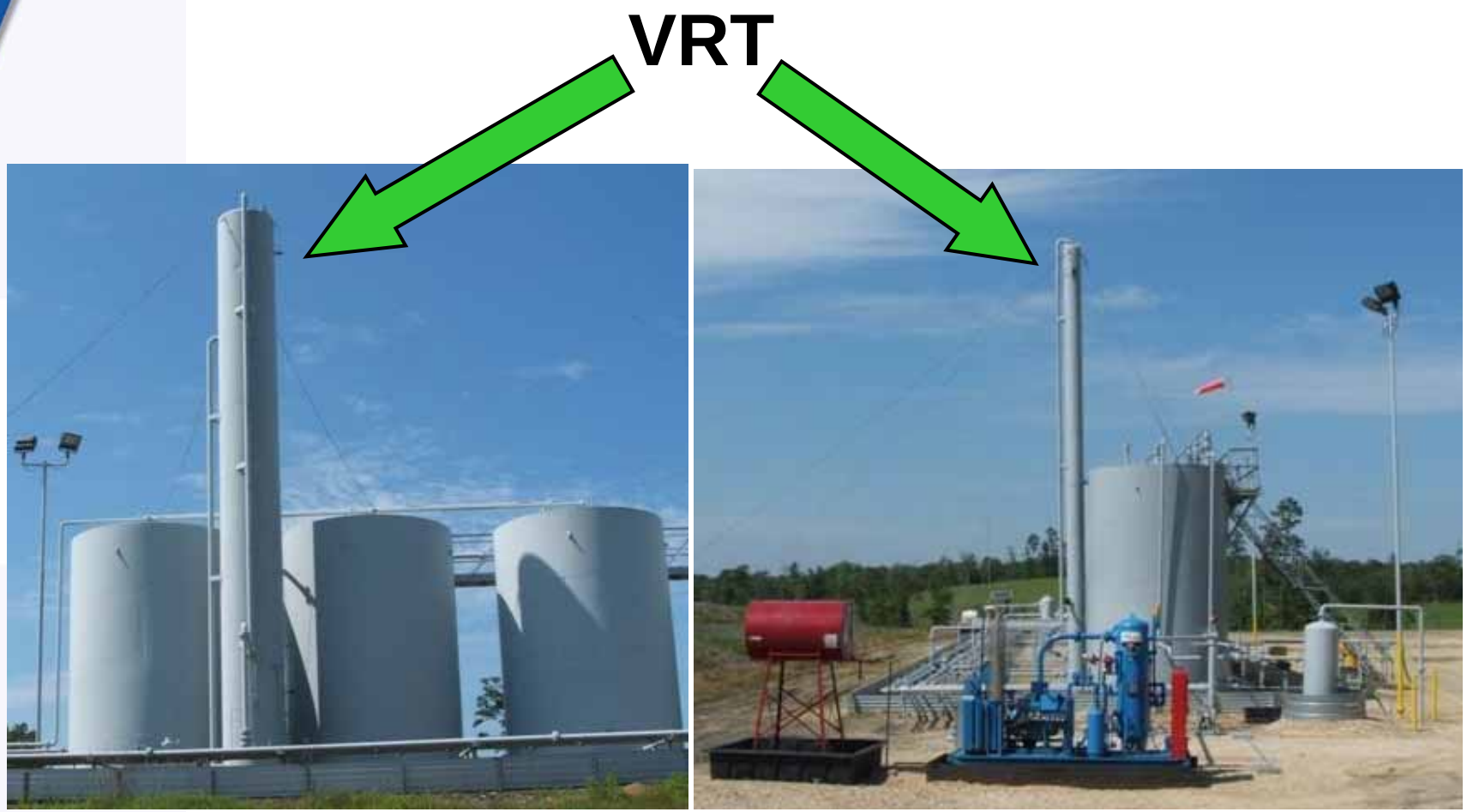
- VRT more tolerant to higher and lower pressures

  蒸汽回收塔可承受更高和更低的压力

- Stable pressure allows better operating factor for VRU

  稳压是蒸汽回收装置更好的运行因素

VRT/VRU Application
蒸汽回收塔/蒸汽回收装置的应用



Source: Anadarko

Industry Experience
工业经验

- 21 companies have reported using VRUs since 1990

  自1990年以来已有21家单位报道使用蒸汽回收装置

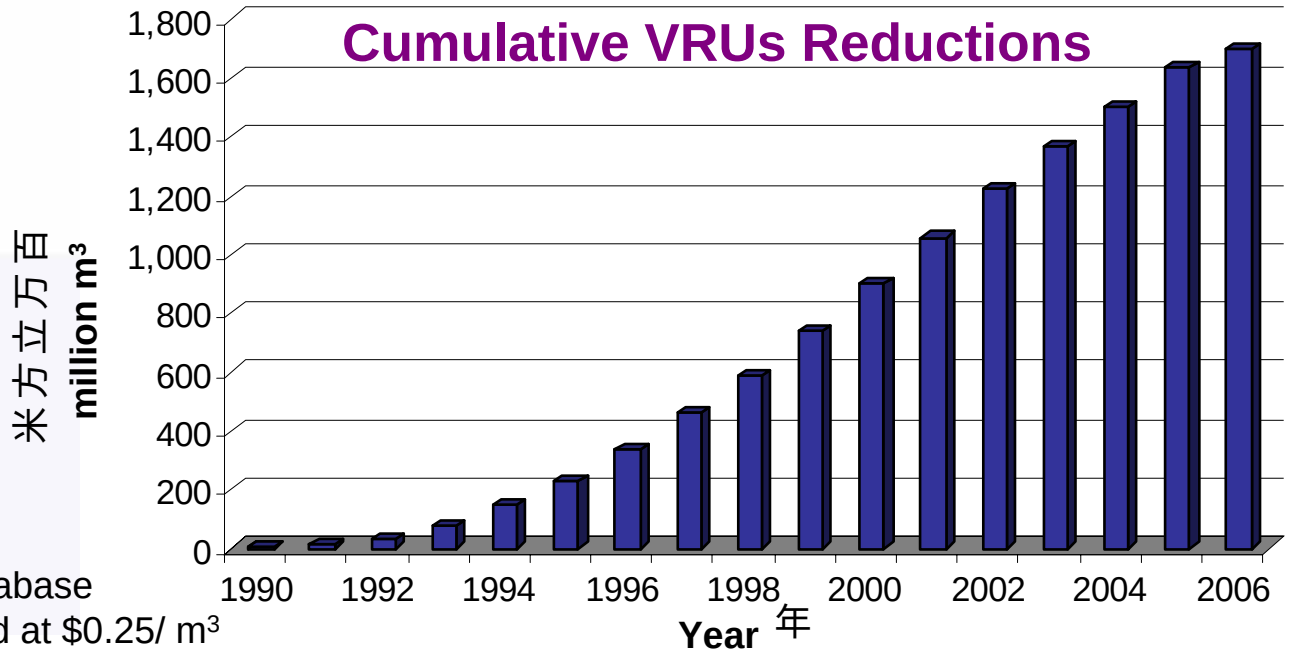
  – Saving 1,695 million m^3 of methane[1]

    节省甲烷1,695百万立方米

  – Worth nearly $424 million[2]

    价值约为424百万美元

蒸汽回收装置节省蒸汽量渐增



[1] iSTAR database

[2] Gas valued at $0.25/ m^3

Methane Losses from Centrifugal Compressors
离心压缩机上的甲烷损失

- Centrifugal compressor wet seals leak little gas at the seal face

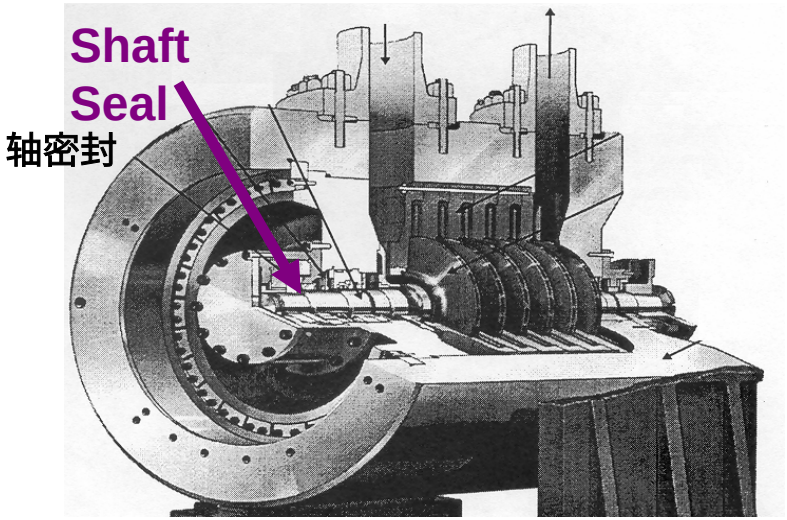
  离心压缩机湿封在密封表面泄漏少量气体

  - Seal oil degassing may vent 1.1 to 5.7 m^3/minute to the atmosphere

    密封油向大气中排气1.1～5.7m^3/min

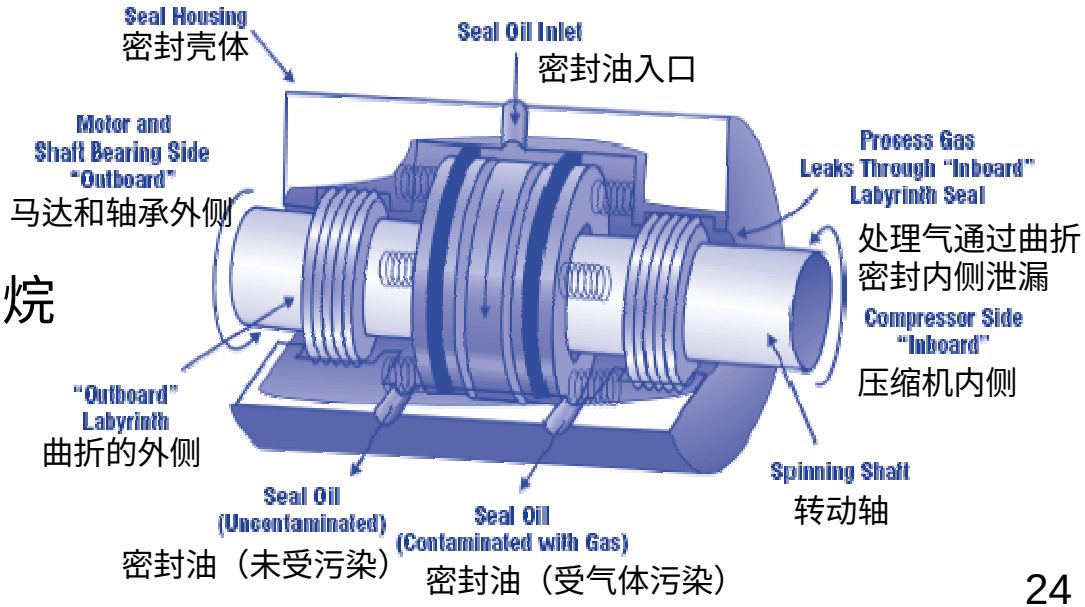
  - One instance of wet seal emissions was as high as 2,124 m^3/day

    一个湿封每天泄漏气体高达2,124m^3/d



Centrifugal Compressor Wet Seals
离心压缩机湿封

- High pressure seal oil circulates between rings around the compressor shaft
  高压密封油在压缩机轴周围的环之间循环
- Gas absorbs in the oil on the inboard side
  气体溶入压缩机内侧的油里
- Little gas leaks through the oil seal
  少量气体通过油封泄漏
- Seal oil degassing vents methane to the atmosphere
  密封油向大气中释放甲烷



Methane Recovery: Dry Seals
甲烷回收：干封

- Dry seal springs press stationary ring in seal housing against rotating ring when compressor is not rotating
  当压缩机不转动时，干封弹簧把密封仓内固定环挤压在转动环上
- At high rotation speed, gas is pumped between the seal rings creating a high pressure barrier to leakage
  高速旋转的条件下，气体在密封环之间流动，形成一道阻止气体泄漏的高压屏障
- Only a very small amount of gas escapes
  只有少量气体逸出
- 2 seals are normally used in tandem
  通常串联两个密封
- Can operate for compressors up to 208 kg/cm^2 safely
  压缩机安全运行高达208kg/cm^2

在离心式压缩机中用干封替代湿封

REPLACING WET SEALS WITH DRY SEALS IN CENTRIFUGAL COMPRESSORS

1 内容提要

离心式压缩机广泛用于天然气开采和输送过程中。旋转轴上的密封阻止高压天然气从压缩机机箱中逸出。这些密封通常使用高压密封油来阻止气体逸出。天然气 STAR 合作伙伴发现，用干封替代“湿”（油）封能极大地降低经营成本和甲烷排放量。

Methane Recovery: Dry Seals
甲烷回收：干封

- Dry seals typically emit at a rate of less than 0.2 m^3/minute

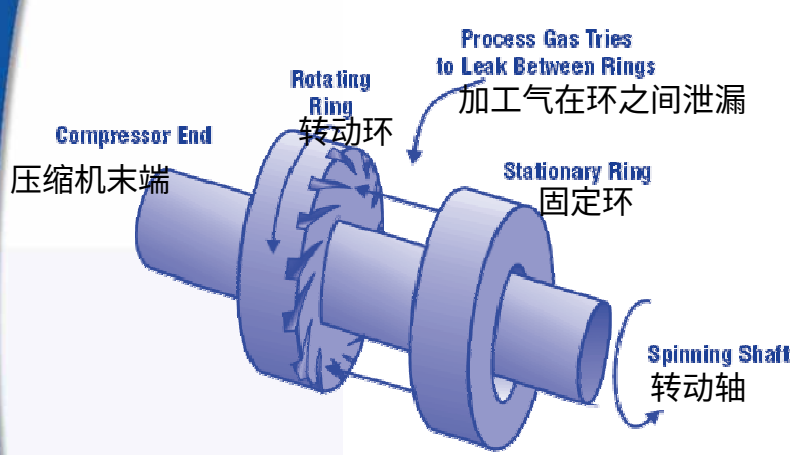
  典型干封泄漏速率小于0.2m^3/min

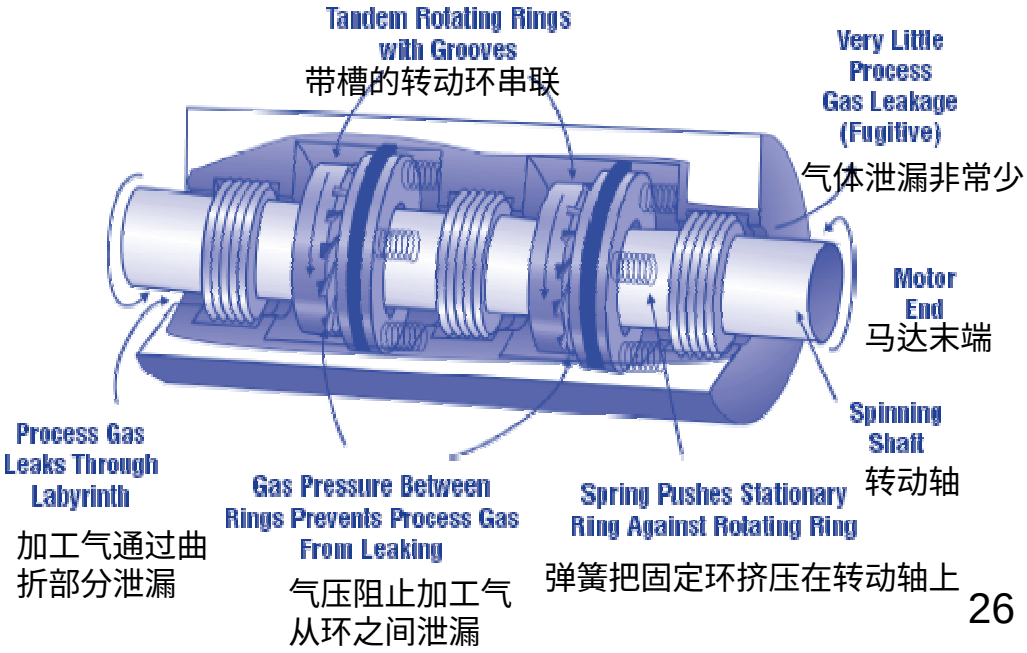
  - Significantly less than the 1.1 to 5.7 m^3/minute degassing emissions from wet seals

    从湿封泄漏气体速率1.1～5.7m^3/min

- Gas savings translate to approximately $112,000 to $651,000 at $250/ thousand m^3

  在气体价格为250美元/km3时，节省价值约为112,000~651,000美元。





Methane to Markets

Economics of Replacing Seals
替换密封的经济性

- Compare costs and savings for a 15 centimeter (6 inch) shaft beam compressor

15cm（6英尺）压缩机的费用与节省价值对比

	Cost Category 费用目录	Dry Seal ($) 干封	Wet Seal ($)湿封
	Implementation Costs[1] 实施费用		
密封费用	Seal costs (2 dry at $4,000 per shaft-cm, with testing)	$162,000	
密封费用	Seal costs (2 wet at $2,000 per shaft-cm)		$81,000
其他费用	Other costs (engineering, equipment installation)	$162,000	$0
总实施费用	Total Implementation Costs	$324,000	$81,000
每年运行费用	**Annual Operation and Maintenance** 每年运行和维护费用	$14,100	$102,400
每年甲烷排放	**Annual Methane Emissions[2]**(8,000 hours per year)		
干封0.2m³/min	2 dry seals at a total of 0.2 m³ per minute	$20,160	
湿封2.8m³/min	2 wet seals at a total of 2.8 m³ per minute		$336,000
5年总费用	**Total Costs Over 5-Year Period**	$495,300	$2,273,00
5年干封节省	**Total Dry Seal Savings Over 5 Years**		
节省	Savings	$1,777,700	
甲烷泄漏减少	Methane Emissions Reductions (1,300,000 m³ per year)	6,500,000	

[1] All costs and revenues are represented in U.S. economics.
[2] Gas price $250/thousand m³

Is Recovery Profitable?
蒸汽回收有效益吗？

- **Replacing wet seals in a 15 centimeter (6 inch) shaft beam compressor operating 8,000 hours per year**

  替换每年运行8,000小时的15cm（6英寸）压缩机上的湿封

  - Net Present Value = $1,216,000

    净现值＝1,216,600美元

    - Assuming a 10% discount over 5 years

      假定5年折现10%

  - Internal Rate of Return = 125%

    内部回收率＝125%

  - Payback Period = 10 months

    回收期＝10个月

    - Ranges from 4 to 16 months based on wet seal leakage rates between 1.1 and 5.7 m^3/minute

      泄漏速率在1.1～5.7m^3/min之间的湿封回收期为4～16个月

- **Economics are better for new installation**

  对于新装置经济效益更好

Note: All costs and revenues are represented in U.S. economics
注意：所有费用和收益根据美国经济确定

Methane Losses from Reciprocating Compressors
交换式压缩机上的甲烷损失

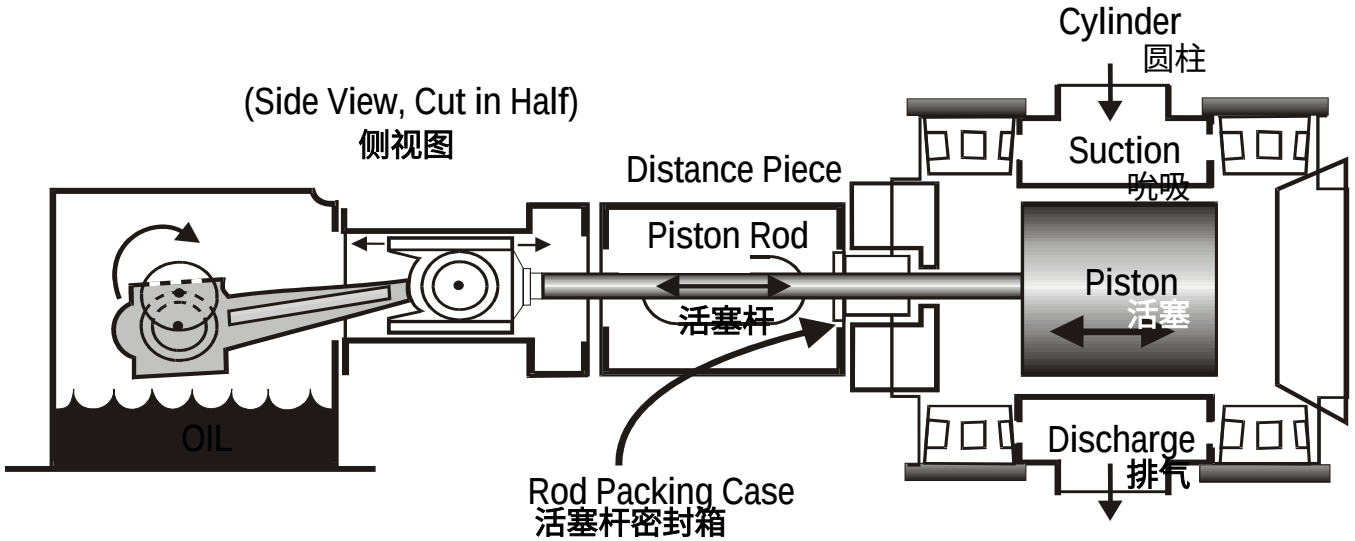
- Reciprocating compressor rod packing leaks some gas by design

  交换式压缩机活塞杆密封泄漏一些甲烷

  - Newly installed packing may leak 0.3 to 1.7 m^3/hour

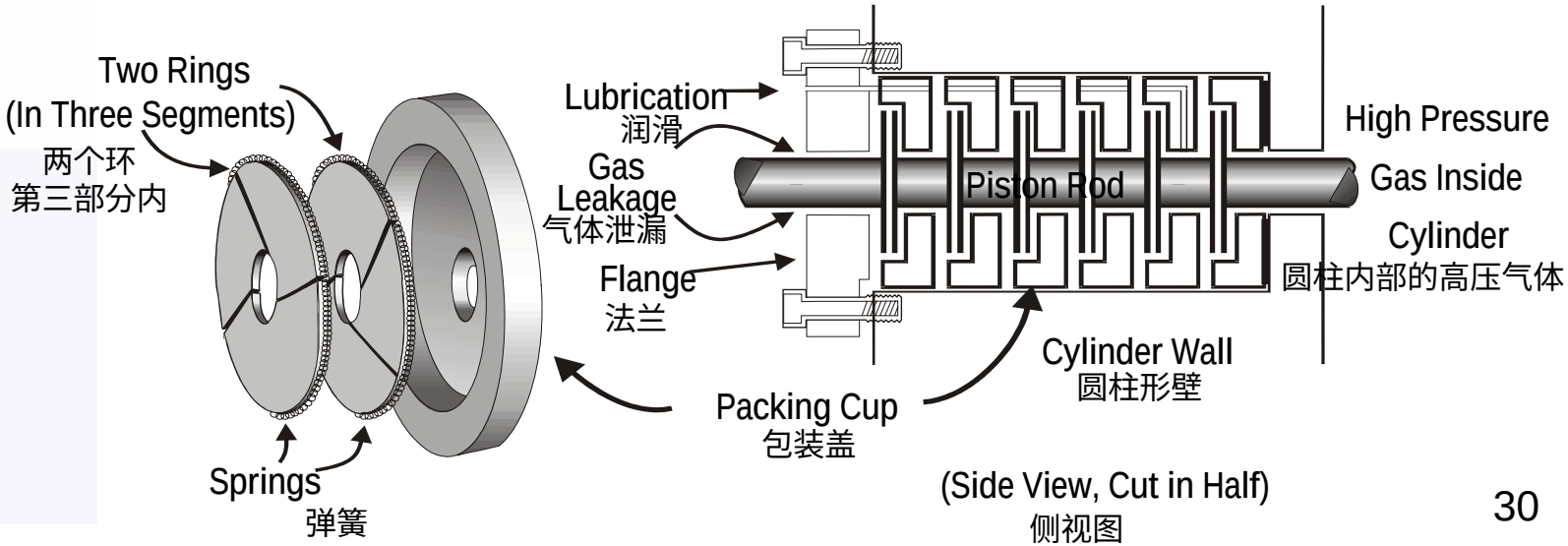
    新安装包装泄漏速度0.3～1.7m^3/小时
  - Worn packing has been reported to leak up to 25.5 m^3/hour

    已有报道，破损密封泄漏速率为25.5m^3/小时



Methane Losses from Reciprocating Compressors
交换式压缩机上的甲烷泄漏

- A series of flexible rings fit around the shaft to prevent leakage
  轴周围的一系列活动环阻止甲烷泄漏
- Leakage may still occur through nose gasket, between packing cups, around the rings, and between rings and shaft
  泄漏仍可能发生在垫圈，包装盖之间，环周围，环和轴之间



Methane Losses from Rod Packing
活塞杆密封上的甲烷泄漏

Emission from Running Compressor 运行压缩机上泄漏	24,600	m^3/year-packing
Emission from Idle/Pressurized Compressor 闲置/加压压缩机上泄漏	36,000	m^3/year-packing
Leakage from Packing Cup 包装盖上泄漏	19,500	m^3/year-packing
Leakage from Distance Piece 隔圈上泄漏	8,500	m^3/year-packing

运行压缩机活塞杆密封装泄漏

Leakage from Rod Packing on Running Compressors

包装类型 Packing Type	Bronze 铜	Bronze/Steel 铜/钢	Bronze/Teflon 铜/聚四氟乙烯	Teflon 聚四氟乙烯
泄漏速率 Leak Rate (m^3/year)	17,300	15,700	37,300	5,900

闲置/加压压缩机活塞杆密封泄漏

Leakage from Rod Packing on Idle/Pressurized Compressors

包装类型 Packing Type	Bronze 铜	Bronze/Steel 铜/钢	Bronze/Teflon 铜/聚四氟乙烯	Teflon 聚四氟乙烯
泄漏速率 Leak Rate (m^3/year)	17,400	N/A	36,500	5,400

Source: Cost Effective Leak Mitigation at Natural Gas Transmission Compressor Stations – PRCI/ GRI/ EPA PR-246-9526

Methane Recovery: Economic Rod Packing Replacement
甲烷回收：经济的活塞杆密封替换

- Threshold exists after which rod packing replacement becomes economic (see technical document for threshold calculation)

  活塞杆密封替换成为经济的后存在阈值（见阈值计算的技术资料）

  - Threshold is typically reached before standard maintenance replacement practices

    标准维修替换之前通常达到阈值

  - Replacement can recover up to 25.2 m^3/hour
    替换能恢复到25.2m^3/小时

减少压缩机活塞杆密封系统中的甲烷排放量

REDUCING METHANE EMISSIONS FROM COMPRESSOR ROD PACKING SYSTEMS

1 内容提要

在美国天然气工业中，处于运转状态的往复式压缩机数量超过 29 000 台，平均每台压缩机有 4 个气缸，即有 160 000 个活塞杆密封系统处于在役状态。这些系统每年向大气中排放的甲烷量超过 438 亿立方英尺，是天然气压缩站中最大的排放源之一。

Is Rod Packing Replacement Profitable?
替换活塞杆密封有效益吗？

- Periodically measure leakage increase

  周期性测量泄漏增加

Rings Only[1] 环

环 Rings: $1,620

活塞杆 Rod: $0

运行时间 Operating: 8,000 hours per year 小时/年

预计泄漏减少 Leak Reduction Expected (m^3/hour)	Payback[2] (years) 回报（年）
1.7	0.5
0.9	1
0.5	2
0.3	3

Rod and Rings[1]

环 Rings: $1,620 **活塞杆和环**

活塞杆 Rod: $9,450

运行时间 Operating: 8,000 hours per year 小时/年

预计泄漏减少 Leak Reduction Expected (m^3/hour)	Payback[2] (years) 回报（年）
11.9	0.5
6.1	1
3.2	2
2.2	3

[1] All costs represented in U.S. economics

[1]所有费用计算与美国经济一致

[2] Gas price of $7/Mcf ($250/thousand m^3)

[2]气体价格7美元/Mcf（250美元/km^3）

Industry Experience
工业经验

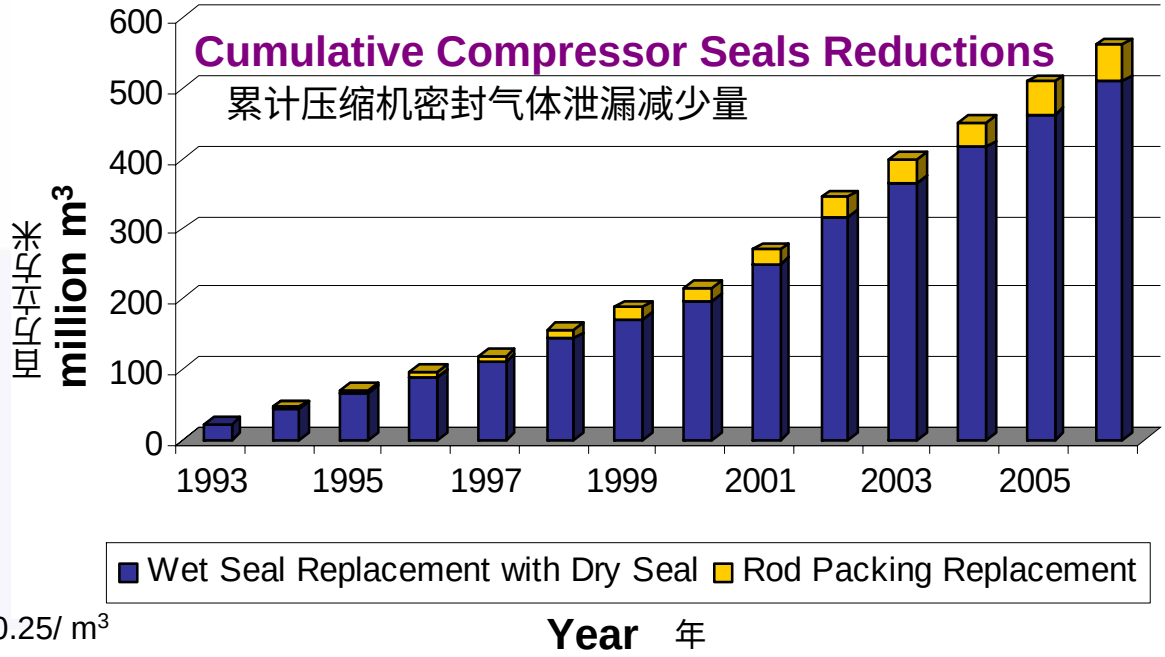
- 17 companies have reported reducing emissions from compressor seals

有17家公司报道降低了从压缩机密封处发生的泄漏

  - Saving over 560 million m^3 of methane[1]

    节省甲烷超过560百万立方米
  - Worth over $140 million[2]

    价值超过140百万美元



[1] iSTAR database
[2] Gas valued at $0.25/ m^3

Compressor Engine Emissions Solution
压缩机引擎泄漏解决方法

- Install automated air/fuel ratios on compressor engines 1,000 to 3,000 Hp

  在压缩机引擎上安装空气/燃料比自动控制装置1,000～3,000Hp

  - Increases combustion efficiency, saves fuel gas and reduces emissions

    提高燃烧效率，节省燃料气，降低泄漏

Source: REM Technology Inc.

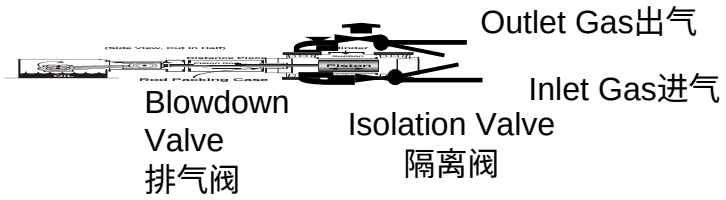
Automated Air/Fuel Ratio Controls

合作伙伴推荐的甲烷减排机会（PRO） NO. 111

适用领域：	压缩机/发动机 ■
■生产部门 ■处理加工部门 ■输气和配气部门	脱水器 □
报道 PRO 的合作伙伴：	管线 □
Chevron Texaco	气动/控制 □
其他相关的 PRO：	储罐 □
减少用天然气启动发动机的频率，用空气启动器代替天然气启动器，更换点火系统——减少启动失败次数，用氮气启动发动机	阀门 □
	井 □
	其他 □

Offline Compressor Emissions Solution
压缩机离线泄漏解决方法

- Reducing emissions when taking compressors offline
  减少压缩机离线时气体泄漏
  - Blowdown to fuel gas
    排出可燃气体
  - Leave compressor idle pressurized
    闲置压缩机加压
    - Install static seal
      安装静密封



减少压缩机离线时的排放量

REDUCING EMISSIONS WHEN TAKING COMPRESSORS OFF-LINE

1 内容提要

压缩机被广泛用于整个天然气系统，将天然气从生产和处理场站输送到用户配送系统。当压缩

Wet Seal Emissions Solution
湿封泄漏解决方法

- Connect wet seal vent gas to low pressure fuel gas system

  把湿封释放的气体连接到燃气系统上

  - Recover vapors from wet seal degassing

    从湿封上回收蒸汽

  - Use as fuel to power engines, heaters, boilers

    回收蒸汽用作发电机、加热器、锅炉的燃料

    - Reduces emissions

      减少气体泄漏

    - Cuts cost of fuels or displaces gas back into system

      减少燃料费用或代替返回系统的蒸汽

Discussion Questions
问题讨论

- To what extent do you have opportunities to implement these technologies?

  您有机会在何种程度上应用这些技术？

- How could these opportunities be improved upon or altered for use in your operation?

  这些机会对您的操作有多少改善或改变？

- What are the barriers (technological, economic, lack of information, regulatory, focus, labor, etc.) that are preventing you from implementing these practices?

  阻碍您应用这些技术的障碍（技术、经济、信息缺乏、管理、焦点、劳力等）是什么？