天然气球罐失效故障树分析

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摘　要　球罐作为天然气储存的主要手段之一 ,预防它的事故发生 ,提高其可靠性并延长安全使用寿命 ,对于安全生产和国民经济的稳定发展具有十分重要的意义。故障树分析方法是从分析失效因果关系中的顶部事件开始直到底部事件。它是由果到因、自上而下地进行分析 ,具有简明、直观、灵活的特点 ,是工程系统可靠性分析与评价的有效方法。文中对引起天然气球罐发生失效的各个因素进行了系统分析 ,建立了以球罐失效为顶事件的失效故障树。通过对球罐故障树的分析 ,得到了故障树的各阶最小割集 ,确立了天然气球罐失效的主要形式 ,并提出了相应的改进措施。

主题词　天然气储存　球形罐　安全　故障树　分析

天然气球罐作为天然气储存的主要手段之一 ,预防其事故发生 ,提高可靠性并延长安全使用寿命 ,对于安全生产和国民经济的稳定发展具有十分重要的意义。故障树分析作为工程系统可靠性分析与评价的有效方法 ,为天然气球罐失效分析提供了有效手段。

故障树分析方法是从分析失效因果关系中的顶部事件开始直到底部事件 ,由果到因、自上而下地进行分析。该方法具有简明、直观、灵活的特点 ,是工程系统可靠性分析与评价的有效方法。故障树分析方法是一种图形演绎方法 ,一个故障树就是一个逻辑图 ,该图描绘了由于其他事件的发生而使得某些事件一定按照次序发生。故障树并不是一个包括所有可能的系统失效或所有的系统失效原因的模型。故障树分析所关心的只是相应于某特定系统失效模式的顶事件。这样故障树也就只包含那些对顶事件有贡献的故障 ,而且这些故障并不是全部所有的故障 ——只包括那些被分析者认为最可能发生的故障。通过对故障树的分析可以找出系统的薄弱环节 ,从而可采取相应措施加以改善 ,提高产品质量及整体工作的性能。

天然气球罐失效故障树的建立

建立故障树 ,首先要根据顶事件确定原则 ,选取“天然气球罐失效”作为顶事件。顶事件确定后 ,就要寻找导致顶事件发生最直接的、必要的、充分的原

用差分法进行求解 ,从而节省了计算机内存 ,缩短了求解时间 ,提高了计算结果的可信性。

(3) 通过实际计算和实测结果比较 ,表明本文所使用的模型和求解方法是正确的 ,可用于确定管道设计方案 ,敷设方法和运行管理问题。

(4) 由于本文将油气管道和半无穷大土壤联合起来进行研究 ,具有较普遍适用性 ,可用于分析管道停输、启输及正常工况的情况。

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因。经仔细分析,确定引起天然气球罐失效的原因为:罐体开裂和爆炸,任一因素的出现都将可能导致球罐发生失效。然后把引起顶事件发生的各原因分别看作顶事件,采用类似的方法继续往下深入分析,建立以逻辑门符号表示的天然气球罐失效故障树,如图 1 所示,该故障树共考虑了 41 个不同的基本事件。

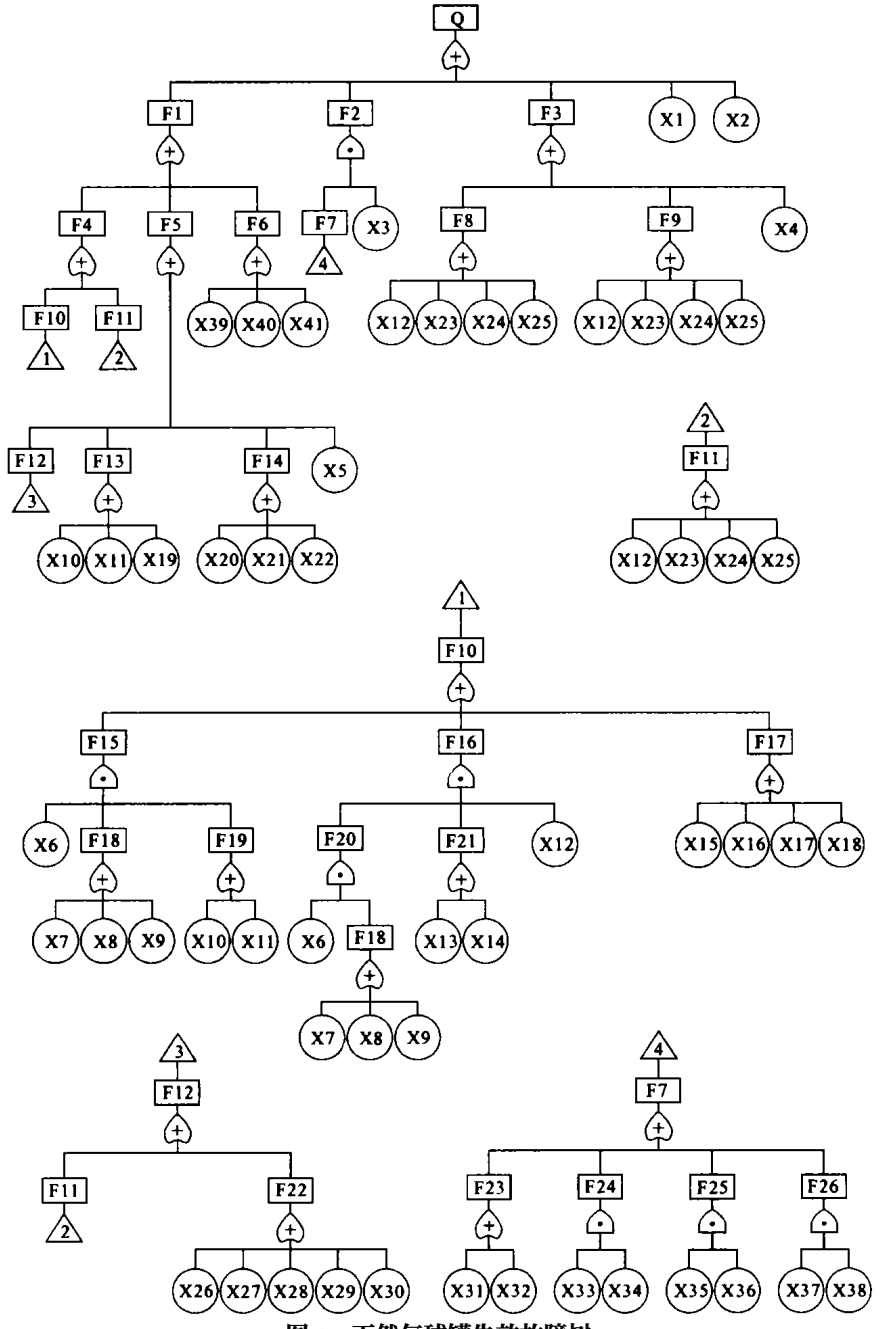

图 1　天然气球罐失效故障树

注:图中各符号所代表的事件分别说明如下。Q 表示天然气球罐失效;F1 表示罐体发生开裂;F2 表示爆炸;F3 表示法兰失效;F4 表示腐蚀开裂;F5 表示承压能力低;F6 表示超压;F7 表示火源;F8 表示法兰破裂;F9 表示法兰联接螺栓断裂;F10 表示腐蚀裂纹;F11 表示材料性能差;F12 表示施工缺陷;F13 表示初始缺陷;F14 表示选材不合理;F15 表示应力腐蚀;F16 表示内腐蚀;F17 表示外防腐绝缘层;F18 表示天然气含酸性介质;F19 表示应力作用;F20 表示内腐蚀环境;F21 表示内防腐失效;F22 表示罐壁焊接;F23 表示明火;F24 表示静电;F25 表示雷电火花;F26 表示电火花;X1 表示误操作;X2 表示蠕变;X3 表示混合气体浓度达到爆炸极限;X4 表示法兰密封圈失效;X5 表示强度设计不合理;X6 表示天然气含水;X7 表示天然气含 H_2S;X8 表示天然气含 SO_2;X9 表示天然气含 CO_2;X10 表示残余应力;X11 表示应力集中;X12 表示材料抗腐蚀性能差;X13 表示内涂层变薄;X14 表示内涂层脱落;X15 表示涂层变薄;X16 表示涂层老化;X17 表示涂层破损;X18 表示涂层粘接力低;X19 表示初始裂纹;X20 表示钢度;X21 表示品种;X22 表示规格;X23 表示热处理差;X24 表示热处理不当;X25 表示材料机械性能差;X26 表示未焊透;X27 表示未熔合;X28 表示过烧;X29 表示焊缝有气孔;X30 表示焊缝夹渣;X31 表示发动机尾气;X32 表示危险区违章动火;X33 表示静电积聚;X34 表示接地不良;X35 表示雷击;X36 表示避雷装置失效;X37 表示电器设施不防爆;X38 表示防爆器损坏;X39 表示球罐出口阀误关闭;X40 表示下游事故出站阀关;X41 表示上游来气量过大。

天然气球罐故障树定性分析

1. 最小割集

故障树定性分析的目的是要找出系统故障的全部可能原因,或导致指定顶事件发生的全部可能起因,并定性地识别系统的薄弱环节。为了达到这一目的,首先应找出故障树的所有最小割集。

凡是能导致故障树顶事件发生的基本事件的集合定义为割集。而最小割集是导致顶事件发生的必要且充分的底事件集合。仅当最小割集所包含的底事件都同时存在时,顶事件才发生;最小割集中有任何一个事件不发生,则顶事件就不会发生。采用"自上而下"的代换方法求出故障树的所有最小割集,将故障树转化为等效的布尔代数方程。见下式:

$$
\begin{aligned}
Q = {} & X1 + X2 + X4 + X10 + X11 + X12 + X15 + X16 \\
& + X17 + X18 + X19 + X20 + X21 + X22 + X23 \\
& + X24 + X25 + X26 + X27 + X28 + X29 + X39 \\
& + X40 + X41 + X3X31 + X3X32 + X3X33X34 \\
& + X3X35X36 + X3X37X38 + X6X7X10 \\
& + X6X7X11 + X6X8X10 + X6X8X11 + X6X9X10 \\
& + X6X9X11 + X6X7X12X13 + X6X7X12X14 \\
& + X6X8X12X13 + X6X8X12X14 + X6X9X12X13 \\
& + X6X9X12X14
\end{aligned}
$$

由布尔代数方程知,天然气球罐失效故障树由 22 个一阶最小割集,2 个二阶最小割集,9 个三阶最小割集,6 个四阶最小割集组成。

由割集理论我们可知,一般情况下,割集的阶数越小,它发生的可能性就越大。因此,故障树中的 22 个一阶最小割集直接影响着系统的可靠性,为系统的薄弱环节。

2. 主要影响因素及改进措施

通过对故障树及其定性分析可以得到引起球罐发生失效的主要因素,从而提高球罐的可靠性。其主要因素如下。

(1) 严重腐蚀

严重腐蚀包括外腐蚀和内腐蚀,主要是内腐蚀。内腐蚀主要是由于腐蚀环境恶劣(天然气含水、含酸性介质、含硫化物)、材料选择不当、抗腐蚀能力弱、焊缝处理不当等原因引起。严重腐蚀导致防腐层失效、罐壁减薄、焊缝产生腐蚀裂纹甚至发生罐体开裂。针对这种情况,应对内外防腐、脱水及天然气含量进行定期检测与分析,采取积极的防腐措施,以防止或延缓腐蚀的发生。

(2) 材料缺陷

主要是材料初始缺陷和施工缺陷。初始缺陷是材料在制造加工、运输、存储、现场装卸不当造成,而在焊接前又未被查出。施工缺陷是在罐体的建造施工过程中形成的,如防腐涂层质量差、焊接质量差等。材料缺陷的存在将直接导致球罐整体强度的降低,特别是在焊缝区形成大量裂纹,直接影响到球罐运行的可靠性。针对这种情况,应严格地按设计要求选材,加强对材料质量的检查,建立严格的施工质量检查制度并遵照执行,选择合理的焊接工艺和高水平的焊工。

(3) 误操作

误操作一直是引起设备失效的主要因素之一。针对这种情况,需严格强调安全管理规程,加强操作人员的培训,以提高其素质和责任心。

结　论

(1) 故障树分析法具有简明、直观、灵活的特点,是进行工程系统可靠性与安全分析及评价常用的有效方法。

(2) 建立了天然气球罐失效故障树,该故障树一共考虑了 39 个基本事件。通过对故障树定性分析确定了天然气球罐运行管理中的薄弱环节。

(3) 对故障树的进一步分析确定了引起球罐失效的主要原因,提出了相应的改进措施,这对于预防或减少球罐发生失效提供了帮助。

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proves recovery rate

SUBJECT HEADINGS: Zhongyuan Oil Field ,Low temperature separation ,Light hydrocarbon recovery plant , Technology design ,Disposal ,Rate.

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LONG GAS PIPELINE DESIGN OPTIMIZATION SYSTEM[1)]

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ABSTRACT: With the theory of decision supporting system combining the gas transmission theory ,the gray system theory , and the optimization theory ," Gas Pipeline Design Optimization System (GPDOS) " has been developed. Using the system , although rugged topography and several gas entering and distributing points along the line ,the optimization of design project of the long gas pipeline is realized. The article introduces the basic process of GPDOS design , i. e. conceptual design ,functional design ,and structural design. Real cases operated in GPDOS show that advantages of the system are ;the process calculation and project optimization of long gas pipeline is automated ; and the random combination of different project calculation can be conducted. Also ,the system is very useful to optimize the investment and operation cost , shorten the optimization cycle pf pipeline design project ,speedily achieve a lot of optimum parameters of the gas pipeline ,such as pipe diameters and wall thickness of different sections ,positions and quantity of gas compression stations ,types and patterns of compressors ,and pressure of gas transmission ,etc. ,and improve the design quality. Also ,the system promotes to renew design idea ,and have engineering design considered by the thinking method of system theory.

SUBJECT HEADINGS: Gas pipeline ,Design , Project ,Optimum seeking method , Automation , Fuzzy mathematics , Decision , Program

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STEFAN ANALYSIS OF SOIL DRY OR THAW AROUND BURIED PIPELINE UNDER INFLUENCE OF THERMAL CONDITION[1)]

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ABSTRACT: The warm oil/ gas will cause evaporation of moisture or thawing of ice rich soil adjacent the pipeline when the pipeline goes through the moist zone or permafrost ,resulting in dry or thaw settlement of the pipeline and heterogeneous sinking of the oil and gas pipeline ,which makes the force borne by the pipeline changing , even damages the integration of the pipeline. Also , the physical property of the soil in the dry or thaw circle will vary. Omitting the variation ,the reasonableness of thermal calculation will be influenced. Therefore ,it is necessary to analyze the variation of the dry or thaw circle around the pipeline for pipeline design , construction and management. In this paper , considering the influence of oil/ gas pipeline on the around soil and the heat transmission of semi-infinite soil , a mathematic model that describes heat transmission of soil has been developed. Since it involves the phase change and multi-phase interface change ,the model belongs to Stefan issure. With treating the model mathematically ,the characteristic equation is derived to calculate the dry or thaw circle. The equation is solved with difference methods ,and the satisfactory results are obtained ,which verifies the calculation method is feasible.

SUBJECT HEADINGS: Buried pipeline , Soil , Phase change , Thermal calculation ,Mathematical model

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FAULT TREE ANALYSIS OF GAS SPHERICAL TANK FAILURE[1)]

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ABSTRACT: Spherical tank is one of the main tools for gas storage. It is very important to prevent the tank from accidents ,

improve its reliability ,and expand its using life for safety of gas production and development of domestic economy. The fault tree analyzes the causality of failures from the top tree event to the bottom tree event. It means the analysis is conducted from the results to the causes ,from the top to the bottom. The method has the characteristics of simplicity , easy understanding , and flexibility ,and is an effective method for reliability analysis and evaluation of engineering system. The article analyzes all factors that may make the spherical tank failure ,and builds a fault tree with failure of spherical tank as the top event. With the fault tree analysis ,the minimum cut-set of the fault tree is obtained. The major way of spherical tank failure is verified. And the corresponding measures are suggested.

SUBJECT HEADINGS: Gas storage , Spherical tank , Safety ,Fault tree ,Analysis.

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DISCUSSION ON FACTOR COST CONTROL MODEL OF NATURAL GAS ENTERPRISES[2)]

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ABSTRACT: Owing the development demand of natural gas industry in enternal and external conditions ,the cost contents of gas enterprises are expanded. It is necessary to innovete cost control model. On the basis of analysing factor cost control theory ,the factor cost control model of natural gas enterprises is set up. The thought on strategy cost management and the kernel idea of staff cost control are reflected by the model. The cost control key is the enternal and external conditions of gas enterprises. Cost control impetus and method are expounded ,and the new idea and new way for cost control are put forward in this paper.

SUBJECT HEADINGS: Petroleum , Natural gas , Enterprise ,Factor , Gas cost ,Control ,Model ,Measure

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PAY ATTENTION TO THE RISK OF INDUSTRIAL CHAIN IN GAS DEVELOPMENT & UTILIZATION[1)]

Liu Yijun (China Mining Technology University ,Beijing) ,Jiang Haichao (Petroleum University , Beijing) . *NATUR. GAS IND*. v. 23 ,no. 6 ,pp. 150～154 ,11/ 25/ 2003. (ISSN1000 - 0976 ; **In Chinese)**

ABSTRACT: Today ,China is in the stage of developing and utilizing gas resource on a large scale. After defining the concept of gas industrial chain ,aiming to rapid development and characteristics of gas industrial chain ,the article proposes the concept of risks for gas industrial chain. Based on the concept of risks , the article fully and accurately studies the risks of gas industrial chain caused by the factors such as gas resource ,pipeline network , demand ,configuration ,and financing ,etc. Also ,the article proposes five precautions against the risks. They are: ① adopting active policy to safeguard and accelerate the development of gas industrial chain; ② accelerating and promoting the formation of competition of gas market; ③ reviewing the financing policy for the projects of gas development and utilization; ④ paying high attention to the gas utilization for electric power generating and the development of its market in key regions; ⑤ Setting up the reserve of gas resource as quickly as possible.

SUBJECT HEADINGS: China , Gas industrial chain , Risk analysis , Precautions , Gas production rate , Gas demand , Gas supply , Gas price , Gas consume.

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SURVEY OF CUSTOMER'S SATISFACTION DEGREE ON TECHNICAL SERVICE OF DRILLING ENGINEERING[1)]

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ABSTRACT: Under the condition of buyer-dominated market ,the customer's satisfaction degree is vital for a modern enterprise. Survey of customer's satisfaction degree on technical service of drilling engineering is helpful not only to improve the quality of products and services so as to better meet the cus-