EBOOK 1
WORKED EXAMPLES

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WORKED EXAMPLES

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Worked Examples

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THE AUTHOR'S APOLOGY FOR HIS EBOOK

Over the course of the many years that I have been working in the process industries I have written a number of books and ebooks — mostly to do with risk management and process safety management. Titles that I have published include *Process Safety Management*, *Prestartup Safety Reviews*, *Management of Change*, *Procedures and Training in the Process Industries*, *Process Reliability and Safety*, *Y2K and the Process Industries* (sales of which are not what they were), *Process Risk Management* and *Fault Tree Analysis*. For a list of currently available publications please visit BIN95.com/sutton.

The ebook you currently have in your hand (or on your computer screen) is one in a series that attempts to show how process plant operations can be managed so as to achieve high levels of safety, environmental performance and profitability. My aim is to blend empirical practice with theoretical concepts to create publications that are useful to a wide range of technical professionals and managers in the process industries. My intent is that the publications help you, the reader, develop and manage your long-range plans. At the same time, I also hope that what I write is immediately useful at 8 o'clock on Monday morning.

This particular ebook — *Worked Examples* — provides a set of examples that are used throughout the book/ebook series to illustrate concepts as they are introduced. The examples are fictional but they are based on real-world experience. I expect to update this ebook frequently, so please visit us at our home page, BIN95.com/sutton/ for the latest updates.

As always when I write, my greatest difficulty is in knowing when to stop. At least I can take comfort in the knowledge that I am not the only one to have experienced this difficulty. In his Apology (Preface) to his book *Pilgrim's Progress* the great 17th century Puritan author John Bunyan said, with far greater eloquence than ever I can hope to achieve,

> In more than twenty things, which I set down;
> This done, I twenty more had in my crown,
> And they began to multiply,
> Like sparks that from the coals of fire do fly.
> Nay then, thought I, if that you breed so fast,
> I'll put you by yourselves, lest you at last
> Should prove ad infinitum, and eat out
> The Book that I already am about. . .

Engineering companies express the same concept with the phrase, 'shoot the engineers'. It means that there comes a time when design must stop and construction must start. Project managers use the term 'scope creep' to express the same notion. Projects have an inexorable tendency to grow 'all by themselves' unless someone throws a yellow flag. When I first arrived in New York in the year 1974 I was taught the phrase, ‘Enough is enough already’. There’s a good time to stop writing — and that time is now.

Finally, in every publication that I have written so far I have concluded the preface with the words Edmund Spenser used in the introduction to his poem *Faerie Queene*, ‘Goe little book: thy selfe present’. So it is with this book — it is now in your hands gentle reader. I hope you find it useful.

Finally, in every publication that I have written so far I have concluded the preface with the words Edmund Spenser used in the introduction to his poem *Faerie Queene*, ‘Goe little book: thy selfe present’. So it is with this book — it is now in your hands gentle reader.

Ian Sutton

Houston, Texas
2007

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EBOOK 1
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INTRODUCTION

In order to illustrate many of the concepts and ideas discussed in this series of books and ebooks, five simple worked examples, all of which are fictional, are provided here.

- The first example shows a simple process involving the flow of liquid from a tank into a pressure vessel. This example is used to illustrate the principles and techniques of process hazards analysis.

- The second example is to do with an equipment item that is widely used throughout the process industries: a shell and tube heat exchanger. The example is used to illustrate equipment failure analysis techniques, particularly Failure Modes and Effects Analysis (FMEA).

- The third example, a cooling tower, is used to illustrate the development of operating and maintenance procedures.

- The fourth example illustrates the development and use of risk management systems.

- The fifth and final example is based on a near-miss event that could have lead to a fire or explosion. It is used to illustrate principles of incident investigation and process risk management.

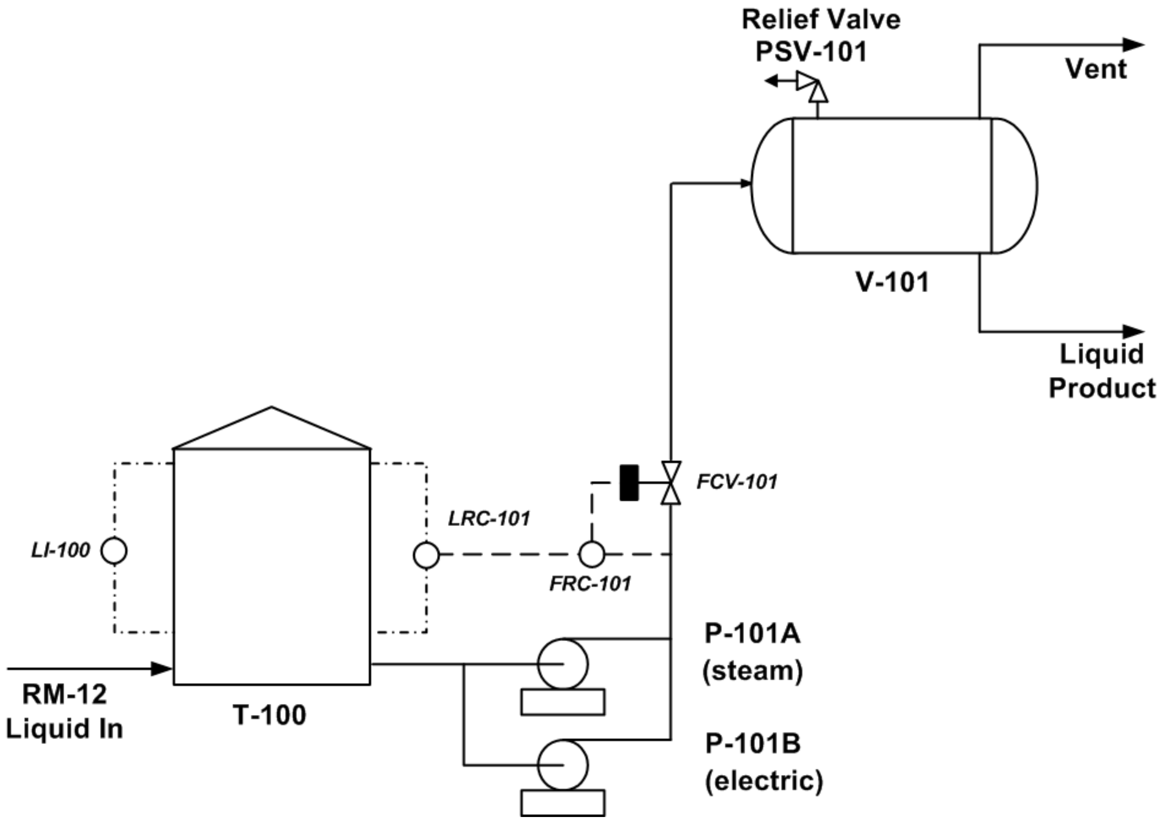
EXAMPLE 1: PROCESS FLOW

Figure 1 shows liquid flowing into an Atmospheric Tank, T-100. The liquid, which is both flammable and toxic, is called Raw Material Number 12 — abbreviated to RM-12. From T-100 RM-12 is pumped to Pressure Vessel, V-101, using Pump P-101A or P-101B, either of which can handle the full flow (A is normally in service, with B being on standby). The pumps are driven by a steam turbine and an electric motor respectively.

The flow of liquid both into and out of T-100 is continuous. The incoming flow varies according to upstream conditions and is outside the control of the operators responsible for the equipment shown. The flow rate from T-100 to V-101 is controlled by FRC-101, whose set point is cascaded from LRC-101, which measures the level in T-100. The level in T-100 can also be measured with the sight glass, LI-100.

V-101 is protected against over-pressure by safety instrumentation (not shown) that shuts down both P-101 A/B, and by the relief valve, PSV-101.

Figure 1
Process Flow Example



Failure and repair times for the pumps are provided in Table 1.

Table 1
Failure and Repair Times

Item	Failure Rate, yr^{-1}	Failure Rate, hr^{-1}	Probability of Failure on Demand	Mean Downtime (MDT), hr
P-101A	0.5	0.000057077	—	8
P-101B	—	—	0.1	3

Summarizing Table 1 in words:

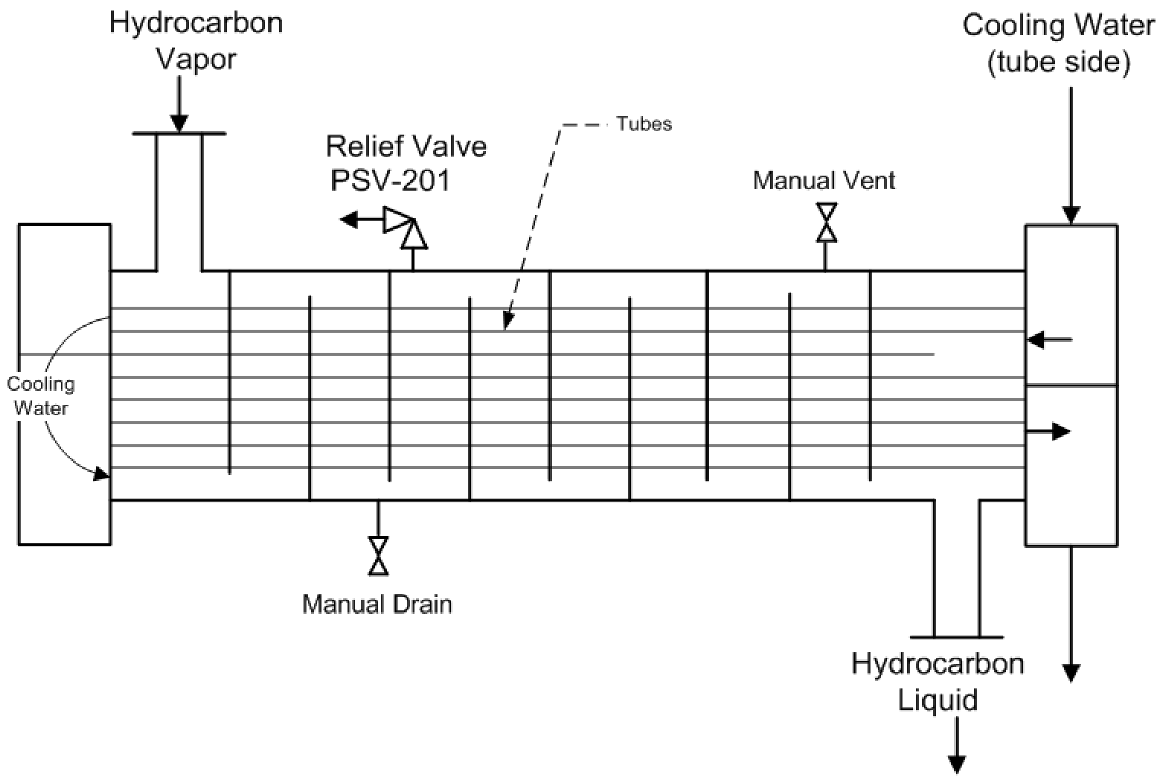
- P-101A (which is the pump that is normally in operation) is expected to fail twice a year. It takes eight hours to repair.
- When P-101A stops working, P-101B is started. It is expected that P-101B will fail to start on demand once in ten times. If P-101B does not start immediately its anticipated repair time is three hours.

This example is used to illustrate the Failure Modes & Effects (FMEA) hazards analysis process in Ebook 3: *Process Risk Management* at www.bin95.com/ebooks/risk_tree_analysis.htm.

EXAMPLE 2: EQUIPMENT

Figure 2 is a sketch of a shell and tube heat exchanger. Hydrocarbon vapors enter the exchanger on the shell side where they are condensed with cooling water which runs through two passes of tubes. The pressure relief valve and the drain and vent valves on the shell side are shown. This example is used to illustrate the application of the Failure Modes and Effects Analysis (FMEA) technique.

Figure 2
Heat Exchanger Example

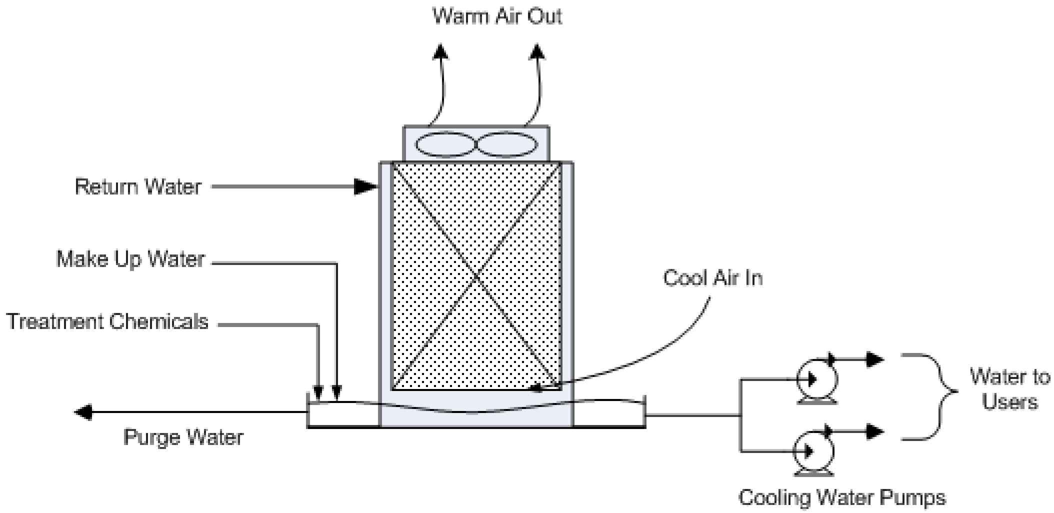


This example is used to illustrate the Management of Change process in Ebook 4: *Management of Change* at BIN95.com/ebooks/change-management-moc.htm.

EXAMPLE 3: OPERATIONS

Figure 3 shows a forced draft cooling tower. Warm cooling water returning from the users enters at the top of the tower and flows down the packing inside the tower into the basin. Air is pulled into the base of the tower by the fans at the top of the tower. The upward flowing air causes evaporation of some of the water thus cooling the water that is not evaporated. The cooled water is pumped to the users. Make up water and treatment chemicals are added to the cooling tower basin as shown. A purge stream controls the build up of dissolved solids.

Figure 3
Cooling Tower Example

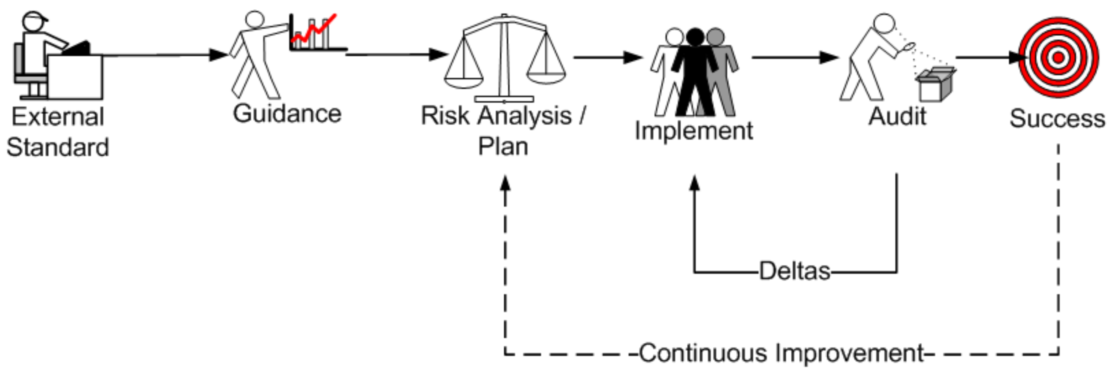


This example is used to illustrate concepts to do with operating procedures, training and overall operations and maintenance in eBook 3: *Procedures and Training in the Process Industries* at BIN95.com/ebooks/standard_operating_procedure.htm.

EXAMPLE 4: RISK MANAGEMENT WORKFLOW PLAN

Many of the concepts discussed in the publications from Sutton Technical Books are to do with risk management. Figure 4 illustrates the major steps in a representative risk management program.

Figure 4
Risk Management Workflow Example



The steps shown in Figure 4 are discussed below.

External Standard

The first step is for an external agency (typically either a government regulator or a company's own corporate group) to create objective standards that are to be followed by the operating facilities and project management teams. Government safety standards are usually quite general in nature (as they should be) because no standards-setting body can conceive of all the different types of operation that fall under their jurisdiction. Government environmental standards, on the other hand, tend to be more prescriptive in nature. Corporate standards are generally quite specific because they can be focused on just those operations that the company carries out.

Guidance

Generally externally-generated standards do not provide enough detail to actually develop and run a risk management program, so additional nuts-and-bolts guidance is needed. Guidance can be internally generated, or it can be provided by outside experts and consultants.

Some larger companies choose to develop a set of 'philosophies' that provide a foundation for many aspects of their work, particularly operations, maintenance, project management and loss prevention. The philosophies, which are basically guidance documents, provide a basis for more detailed design bases and engineering specifications.

Risk Analysis Plan

The next step shown in Figure 4 is to conduct a risk analysis that will help determine what risks exist, how those risks can be mitigated, and how resources should be prioritized. .

Implement

Having prepared the plan the risk management program is implemented.

Audit / Deltas

No management program is perfect. Gaps between goals and reality always exist. With respect to safety, one manager once said, “There is always news about safety, and some of it will be bad”. In order to systematically identify the gaps, audits are needed. If the audit finds deficiencies or gaps, the process recycles to the Implement step, as shown in Figure 4. (The word ‘delta’ is sometimes used to describe the difference between plan and performance because it sounds less critical than words such as ‘deficiency’ or ‘failure’.)

Success / Continuous Improvement

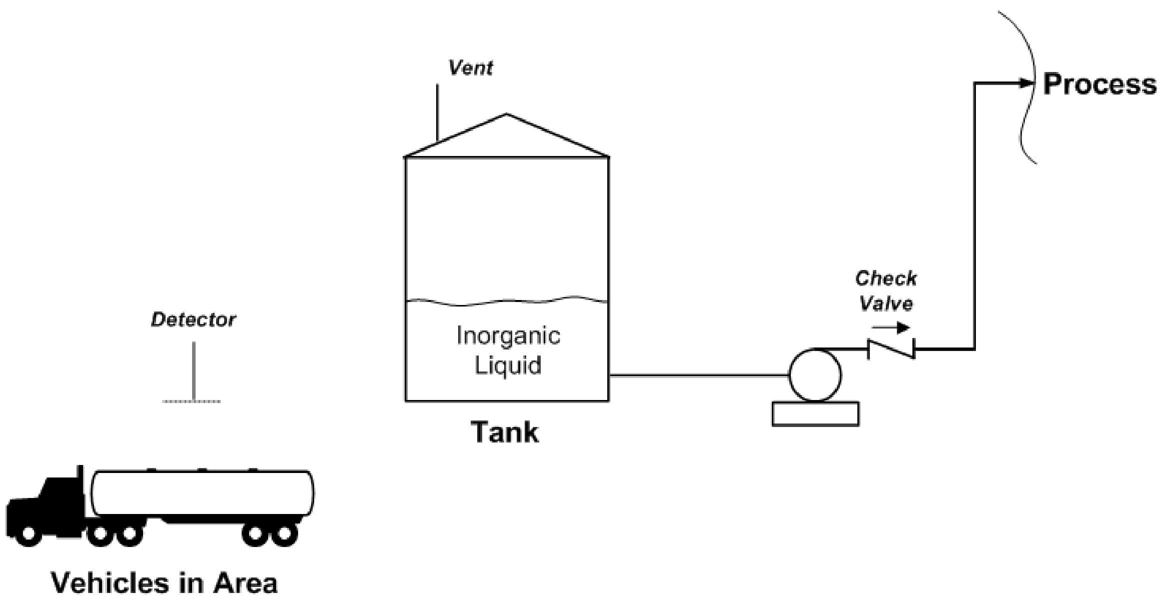
Ideally, once the plan is implemented and has cleared the audit hurdles, management can declare that they have successfully implemented their risk management program. However risk can never be low enough; improvements can always be made. Therefore, once the program shown in Figure 4 is complete, management should start the whole process over again — usually at the risk analysis and planning steps — in order to achieve even higher levels of safety and economic performance.

EXAMPLE 5: SIGNIFICANT POTENTIAL INCIDENT

This example is loosely based on an actual event that occurred at a process facility. Fortunately the incident did not result in a major loss, but it does provide some opportunities for lessons learned.

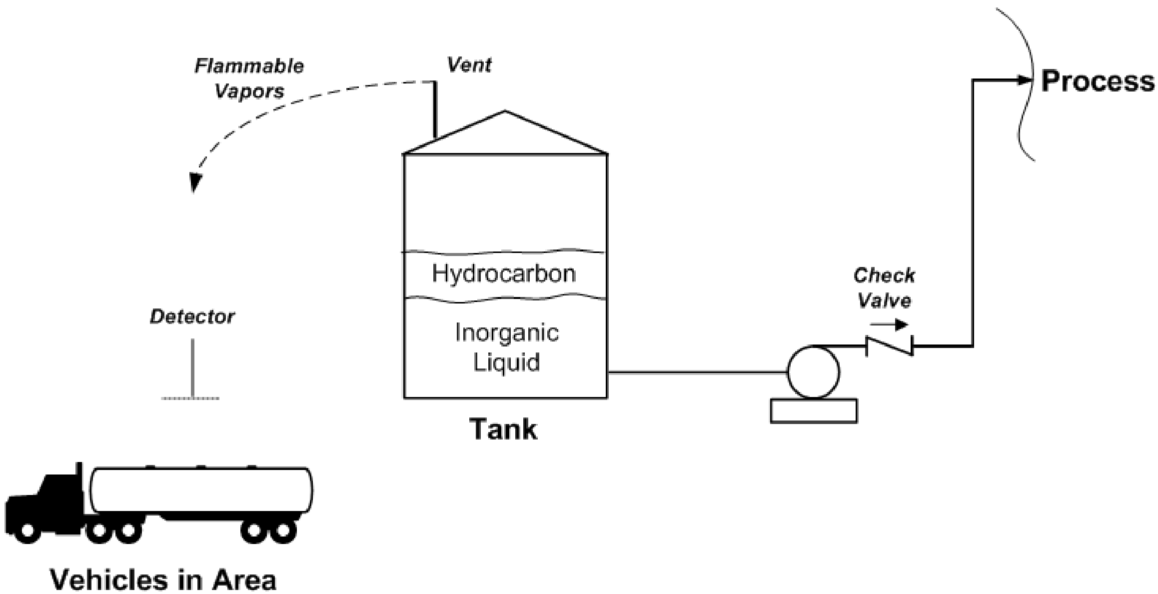
A cone-roof, atmospheric storage tank stores a non-flammable, low vapor pressure inorganic liquid. The vapor space above the chemical is air; the tank breathes in and out through a simple vent line, as shown in Figure 5. Also shown in Figure 5 is a vehicle; one of the facility's private roads runs close to the tank. A steady stream of vehicles uses the road.

Figure 5
Reverse Flow Scenario - 1



The pump stopped operating, the check valve failed to hold and light hydrocarbons flowed backward into the tank. A layer of hydrocarbons formed on top of the inorganic liquid, as shown in Figure 6.

Figure 6
Reverse Flow Scenario - 2



The hydrocarbons in the tank vaporized, then vented to atmosphere as shown. A hydrocarbon detector located about 100 meters from the tank detected the presence of flammable vapors.

The incident was a near miss, *i.e.*, the vapors did not light off, and no one was hurt. (There were, however, economic costs associated with cleaning out the tank safely.) However the potential for a serious event is high — the vapors could have ignited at a vehicle engine. The flame front could have entered the tank and caused the vapors in the tank to explode. (It is worth noting that this event had actually happened some years previously at the same facility in a similar, but not identical process arrangement.)

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