Analysis Patterns for Materials and Products of Refineries [1]

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1. Introduction

We have developed information systems for refineries. These systems cover almost every business level of a refinery, from Unit Operation Systems to Decision Assistant Systems. There have been some obstacles for us to finish these projects. One of them is that we lack knowledge about petroleum engineering. Another one is that we are often confused by the same terms having different meanings for different users. We need to study the domain knowledge. But the problem is how much we should know for developing a Refinery Information System?

It is well known that if the developing team members are familiar with the domain knowledge the developing process becomes easier. But petroleum engineering is far from real life. It is hard to explain some terms to our software engineers. It is costly to let software engineers to learn more about refinery process and petroleum engineering. So we decided to develop a series of analysis patterns as a guide for developing Refinery Information Systems. The audience of this work includes analysts, designers, and programmers. The patterns will help them understand the basic knowledge that they must know to perform a project of this type, and give them a generic analysis model that can be a prototype for their concrete analysis.

The materials and products of refinery mainly are mixtures. They include materials such as crude oil and wax oil, half products such as crude gasoline and naphtha, and products such as 93# gasoline and 0# diesel oil. Due to the complexity of these mixtures and the variety of business contexts, it is impossible and unnecessary to build a unified model that can describe the structures of these mixtures to meet all business requirements. For meeting requirements of different business contexts, we develop corresponding models and build the relations between these models. The patterns of this paper represent these models and the relations between them. They basically describe the materials and products of refinery in different business contexts.

There are four patterns that can be used in different business contexts. There are “Main Property Pattern”, “Material Source Pattern”, “Complex Properties Pattern” and “Mixture Pattern”. The purpose of each pattern is listed in table 1. The relations between these patterns are shown in fig 1.

No	Name	Purpose
1	Complex Properties Pattern	Representing the analysis model of materials or products properties
2	Main Property Pattern	Identifying a materials or a product by its main property
3	Material Source Pattern	Identify a material by its source, such as location, producing scheme or the material that it comes from
4	Mixture Pattern	Representing the contents of a mixture that is mixed by two or more kinds of materials

Table 1 Overview of patterns

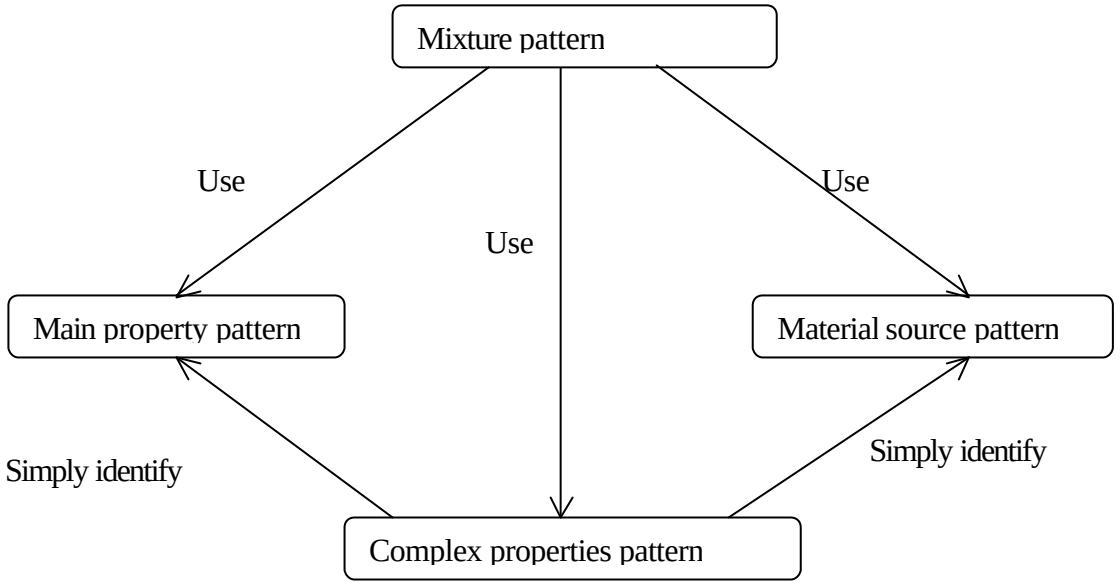

Fig 1 relations between patterns

We use UML to describe the patterns of this paper [Pag2000] [Lar98]. Although the patterns of this paper are analysis patterns, we have used some design patterns [Gam95] for description methods. To illustrate the structures clearly, we also use some process flow drawings that are used in chemical engineering.

2. Complex Properties Pattern

2.1 Intent

A material or a product is identified by a set of properties. This pattern represents the analysis model of materials or products properties.

2.2 Context

We need to know the properties of the materials and products we handel. Each kind of materials and products has its own properties. To identify a material or to examine the quality of a product, you should examine each property. Only when every property meets correlative quality standard, you can say the material or product meets the quality requirement.

There are several different kinds of properties. Some properties can be described as a numerical value such as temperature. Some properties can only be described by using natural language such as the color of material.

In many business systems, the details of materials or products should be known. They include quality control system, crude oil trade systems, products trade systems and oil delivery system, etc. In these systems, each property should be examined and the results should be collected, stored and printed out.

2.3 Problem

How to build a unified model to meet the variety of materials and their properties?

2.4 Forces

- Each kind of material or product has its own properties and we need to keep track of all of them.
- There are several different kinds of properties. They cannot be described by using one method.
- New properties or types may be needed.

2.5 Solution

We define the material class to represent materials and products. This class contains some basic properties such as material's name and description. These basic properties are defined as attributes of the class, because they are shared by all materials and products. We treat this basic properties as fixed properties[Fow1997].

However, most properties of various materials are different. To let various materials share a unified model, we treat properites as dynamic properties[Fow1997]. We define a property class to represent the property of materials. The material class has a

collection that contains property instances. In this way, we can add or remove the properties of a material dynamically and various materials that have different properties can share a unified model.

There are also many types of property. For each type of property, we define a subclass of property class. Two type of properties are often used. The one is numeric property, such as boiling point, melting point and so on. The other is decription property that should be decribed as a word or a sentence, such as color, source and so on.

We also consider the material quality in this pattern. We define a standard material class that contains all suitable property values of a kind of materials. Only when all properties of a material meet property standards, it can be identified as a qualified material.

The structure of this pattern is shown in fig 2.

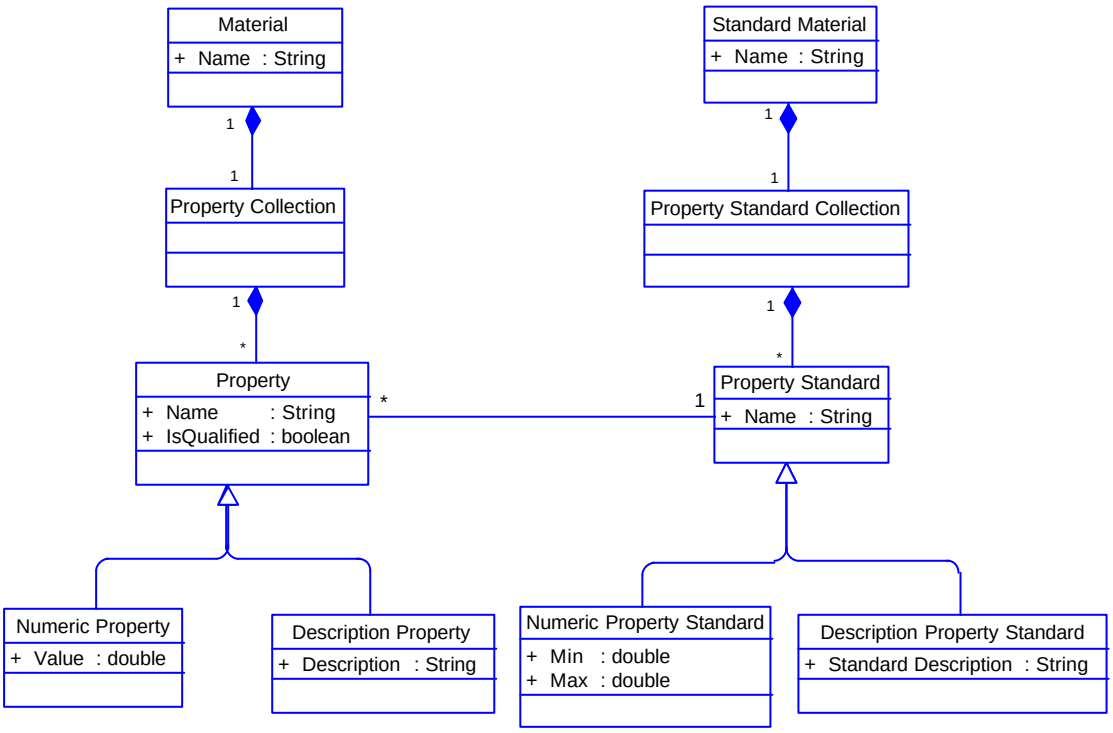

Fig 2 the structure of Complex Properties Pattern

2.6 Example

Following is an example of this pattern. Table 2 shows the properties of a kind of crude oil. The material name is “Middle East Light Crude Oil”. Each row in the table represents a numeric property of the material.

Item	***Result***
API GRAVITY	33.6

SPECIFIC GRAVITY @15.6℃	0.8572
SULPHUR CONTENT WT%	2
REID VAPOUR PRESSURE @37.2℃ CPSL	6.5
IDS CONTENT PPM	12
POUR POINT ℃	-39
SALT CONTENT MG/L	9.2
ASH CONTENT WT%	0.009
ASPHALTENES WT%	1.2
CONRADSON CARBON RESIDUE WT%	4.9
KINEMATIC VISCOSITY @	
37.8℃ CST	6.2
50℃CST	4.6
METAL CONTENT PPM	
NICKEL	13
VANADIUM	29
ASTM DISTILLATIONS	
IBP,℃	30
50℃VOL%	2.2
75℃VOL%	5
125℃VOL%	13
150℃VOL%	18
175℃VOL%	24.6
200℃VOL%	29.5
225℃VOL%	33
250℃VOL%	37.5
275℃VOL%	42.6
300℃VOL%	47.6
TOTAL DISTILLATE,VOL%	47.6
TOTAL RESIDUE,VOL%	51.4

Table 2 properties of light crude oil coming from Middle East

2.7 Consequences

This pattern presents the following advantages:

- It can describe almost every material and products of refinery.
- You can add new type of property easily by adding a new subclass of property. You need not change other parts of the model.
- You can add or remove properties easily and need not change the model.

However this pattern has some disadvantages too:

- It is too complex. In some cases, it is unnecessary to keep all properties of materials and products.
- It cannot describe materials directly. To describe a material, the model needs extra

data of property standard.

2.8 Known Uses

This pattern is used in many management systems of oil refineries, e.g. quality control system and producing control system [Zhang1999].

2.9 Related Patterns

A material has a ***Collection*** [SAN2001] of properties. All other patterns in this paper are related with this pattern.

There are two kind of properties: ***Fixed Property*** and ***Typed Dynamic Property*** [Fow1997].

3. Main Property Pattern

3.1 Intent

This pattern provides a simple method to identify materials or products.

3.2 Context

Some business cases need simple method to identify a material or a product; for example, in oil sales system each kind of gasoline is identified by octane number. In these cases, the material or product is examined and the result is known. It is not necessary to display all properties of materials or products.

3.3 Problem

How to identify a material by using simple method and represent its main property?

3.4 Forces

Most kinds of materials have a main property that can represent the difference of them.

3.5 Solution

We add the main property into the material class so the material class can be used without the property collection. The structure of this pattern is shown in fig 3.

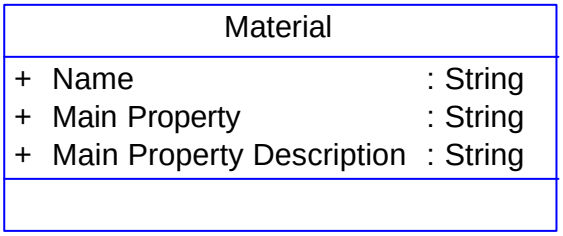

Fig 3 the structure of Main Property Pattern

3.6 Example

For example, in a gas station, only the main properties of products and related prices are

listed, as table 3 shows.

Name	Price(RMB per ton)	Provider
90# gasoline	3980	Sinopec
93# gasoline	4200	Sinopec
97# gasoline	4400	Sinopec
0# diesel oil	3560	Sinopec
-20# diesel oil	3760	Sinopec
90# gasoline	3970	PetroChina
93# gasoline	4025	PetroChina
97# gasoline	4225	PetroChina
0# diesel oil	3600	PetroChina
-20# diesel oil	3800	PetroChina

Table 3 Price of oil products

3.7 Consequences

This pattern presents the following advantages:

- It provides a simple way to identify a material.
- It's easy to link with Complex Properties Pattern.

However, in some cases, a unique property cannot identify a material.

Sometimes a material can be identified by its use, such as heating. It is also possible to represent these cases by this pattern.

3.8 Known Uses

Most oil products are identified by main properties. We also use this pattern to identify some half products. For example, we have created a method to identify wax products by using the percent of paraffin in producing systems.

Sometimes a material can be identified by its usage such as heating. These cases can be represented by this pattern too.

3.9 Related Patterns

When one wants to know the details of a ***Main Property*** material, he can visit the ***Complex Properties*** of this material.

4. Material Source Pattern

4.1 Intent

This pattern provides a method to identify a material or a product by its source.

4.2 Context

Some materials and semi products cannot be identified one property. For example, to represent a kind of crude oil, we need test more than ten items. An interesting thing is there are some relations between the material source and its properties.

4.3 Problem

How to identify a material or a product by using its source?

4.4 Forces

The properties of crude oil have relations with its source.

The properties of some semi products have relations with the unit that produces them and the producing scheme of the unit.

The properties of some semi products have relations with the materials that they come from.

4.5 Solution

We create a source class related with the material class. The source class has three sub classes to deal with corresponding cases listed in forces. There are locution, producing scheme and material source. The structure of this solution is shown in Fig 4.

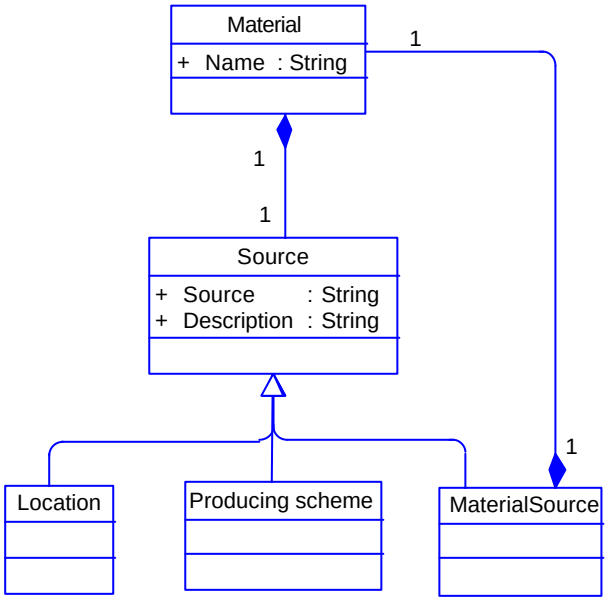

Fig 4 the structure of Material Source Pattern

4.6 Example

For example, crude oil can be identified by its source, as table 4 shows.

CRUDE	API	SULFUR	COUNTRY	LOCATION
Cossack	49	0.04	Australia	North West Australia

Gippsland	48	0.1	Australia	Westernport
Griffin	55	0.03	Australia	Denture, Griffin
Jabiru	42	0.05	Australia	Jabiru Venture, in Timor Sea
North West Shelf	60	0.01	Australia	Dampier
Thevenard	36	0.05	Australia	Thevenard Island
Elang	53	0.03	Australia	Zoca
Daqing	32.7	0.1	China	Luda/Dalian on Yellow Sea
Nanhai Light	39.5	0.05	China	Hui Zhou
Shengli	24	0.9	China	Qingdao on Yellow Sea
Ardjuna	35.1	0.13	Indonesia	Ardjuna
Arun	53.9	0.02	Indonesia	Blanglancang
Attaka	44.7	0.04	Indonesia	Santan, off Balikpapan
Belida	46.2	0.02	Indonesia	Belida
Cinta	32.7	0.11	Indonesia	Cinta
Duri	21.5	0.14	Indonesia	Dumai, Sumatra
Handil	33.8	0.07	Indonesia	Senipah, off Balikpapan
Minas	36	0.08	Indonesia	Dumai, Sumatra
Widuri	33.3	0.07	Indonesia	Widuri
Labuan	31.5	0.08	Malaysia	Labuan Island, off Sabah
Miri	31.9	0.08	Malaysia	Lutong in Sarawak, near Miri
Tapis	46	0.03	Malaysia	Kerteh, off Trengganu
Kutubu	44	0.04	New Guinea	Kumul terminal

Table 4. Some kinds of crude oil and their properties

4.7 Consequences

This pattern presents the following advantages:

- It provides a simple way to identify some complex materials that cannot be identified by a main property.
- It's easy to link with Complex Properties Pattern.

However, there are some disadvantages:

- You cannot know the properties from this pattern directly.
- Sometimes, even two kinds of materials come from a same source; their properties are quite different.

4.8 Known Uses

Most crude oil trade systems use the source of crude oil to identify it.

4.9 Related Patterns

When one wants to know the details of a material or a product, he can visit the ***Complex Properties*** of this material.

Some semi products' sources are ***units or tanks***.

Sometimes this pattern is used with ***Main Property Pattern*** to identify a material or a

product, for example, middle east light crude oil.

5. Mixture Pattern

5.1 Intent

This pattern provides a way to represent the contents of a mixture that is mixed by two or more kinds of materials.

5.2 Context

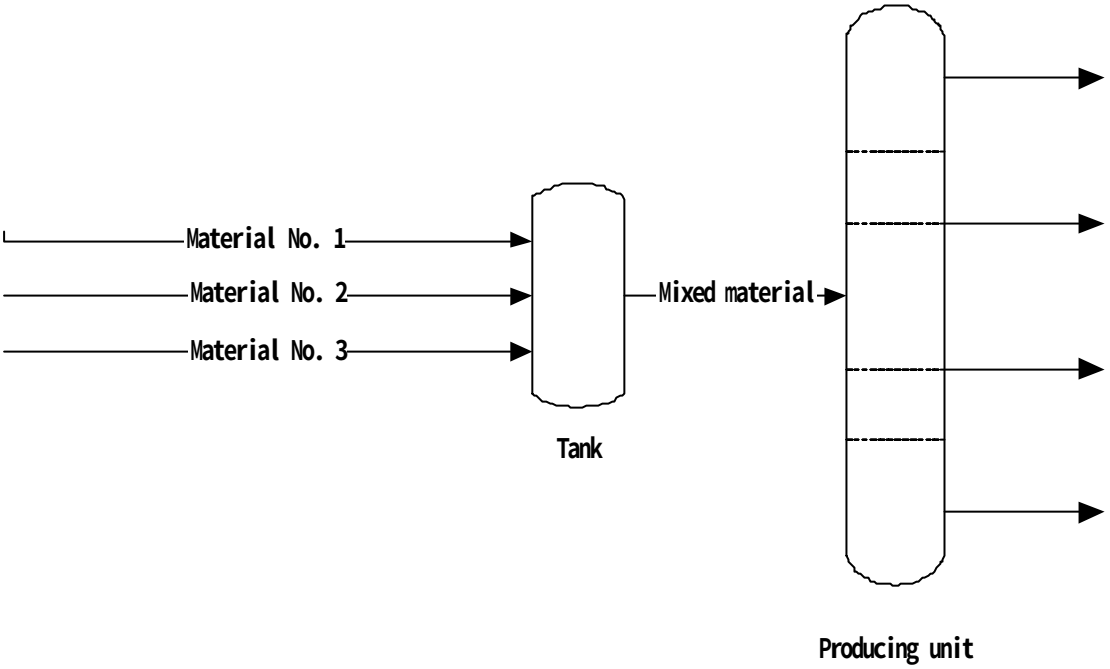

Fig 5 A sample flow process

The oil producing process is a real time process. As shown in Fig 5, before the materials flow into a producing unit, they are stored in tanks. It is unnecessary and impossible to store one material in one tank. Many materials are mixed and stored. However, it is difficult to know what the properties of the mixture, and these properties are very important for choosing producing schemes.

5.3 Problem

How to represent the contents of a mixture that is composed of two or more kinds of materials?

5.4 Forces

The mixture can be mixed by named simple materials and unnamed mixtures.

The mixture itself is a kind of material.

The content of a material or a product in a mixture can be a number between 0% and 100%.

5.5 Solution

The ***Composite Pattern*** [Gam95] can represent the relationship between a thing and the parts of it. However, it cannot represent the content of each material in a mixture. So we extend the composite pattern by adding a material in mixture class that has a content property. The structure of this solution is shown in Fig 5.

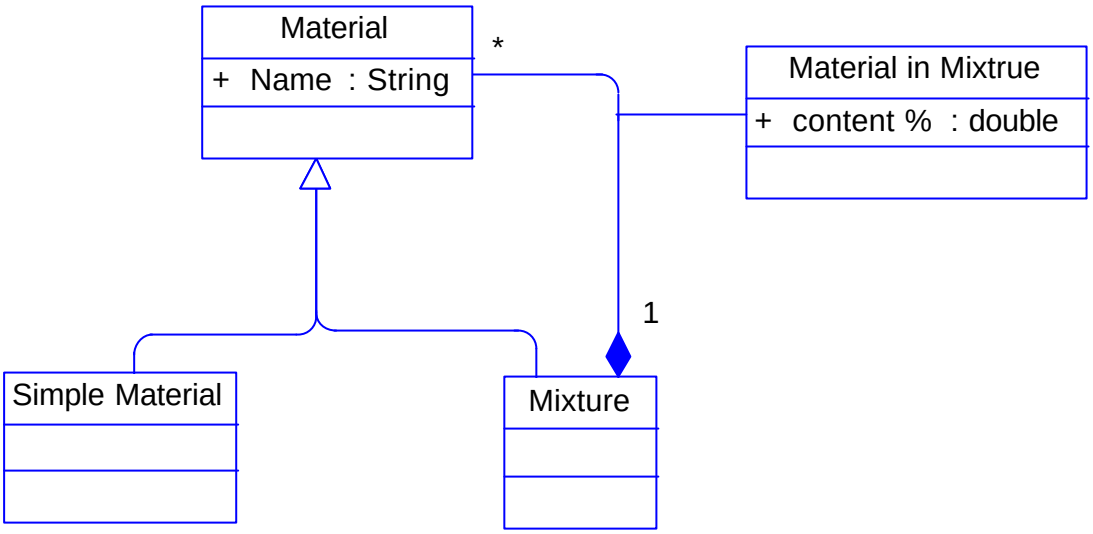

Fig 6 the structure of Mixture Pattern

5.6 Consequences

This pattern presents the following advantages:

- This pattern can represent mixtures that are mixed by simple materials and other mixtures.
- By using this pattern, you can know exactly the contents of a mixture.

However, this pattern cannot provide a mixture a simple name that can identify its properties.

5.7 Known Uses

This pattern is used in many management systems of oil refineries, e.g. producing control systems [Zhang1999].

5.8 Related Patterns

A simple material may be a ***Main Property*** material, a ***Complex Properties*** material or a material coming from a ***Material Source***.

This pattern is a variation of ***Composite Pattern*** [Gam95].

6. Future work

We are developing those patterns to build a complete analysis pattern language for a refinery information system. These patterns include:

- Patterns for oil refineries (workshopped in PloP2002[Zhen2002])

- Patterns for Materials and Products of Refineries (this paper)
- Patterns for Refinery Dynamic Production Process
- Patterns for Refinery Product Quality Control
- Patterns for Refinery Equipment Management
- Patterns for Refinery Storage Management
- Patterns for Refinery Delivery Management
- Patterns for Refinery Measurement Management

There are many other businesses involved in a Refinery Information System (such as Manpower Management), but they are not part of the refinery itself.

7. Acknowledgments

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8. References

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