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Open Interface Specification: Petroleum Fractions Interface



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SUMMARY

This document proposes interfaces for handling complex mixtures of the type of petroleum fractions. The document contains requirements expressed in textual form, as well as Use Cases. From these requirements the corresponding interfaces were developed.

The scope of the interfaces, initially conceived as for handling Petroleum Fractions and Assays, was reduced to only Petroleum Fractions, since this was considered the most crucial and value added part of the interfaces.

The proposed interfaces allow UNIT Operation clients to access properties specific of the petroleum industry such as e.g. cloud point, pour point, Reid vapor pressure, and also to perform run-time re-characterisation of the properties of hypothetical components representing a petroleum fraction (e.g. Normal Boiling Point, Molecular Weight, Specific Gravity, Critical Temperature, etc).

This allows extending plug-and-play of UNIT operation components to the specific operations present in the petroleum and gas industry (e.g. refining, upstream, etc). In particular, these interfaces will allow plug-and-play of refinery reactor operations. These operations present a characteristic problematic, that requires a special treatment, as it is described in this document.

ACKNOWLEDGEMENTS

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1. Introduction

For chemically well-defined fluids, such as petrochemicals, simulators conveniently draw on large data banks of chemical compounds for essential property data whereas for petroleum, a material of indefinite composition, such a direct means of representation is not practical. However, the large number of hydrocarbon compounds that constitute oil behave 'approximately' as ideal fluids, thus making the 'lumping' of 100's of real compounds into 10's of hypothetical compounds an adequate simplifying assumption for many (but not all) process engineering purposes (see later).

Although predominately a hydrocarbon fluid, there are contaminants present in both fossil and synthetic oils, especially the former e.g. sulphur, metals, inert gases and water/brine. These have a significant impact on separation and reaction processes. For instance, the sulphur treating and handling aspect of refining entail many reactors and separations. And, small amounts of metals affect adversely the catalyst activity in the conversion processes.

1.1 Properties

1.1.1 Petroleum Basic Properties

A detailed analysis of crude oil, by compound, up to carbon number 6 is usually obtainable and the C6+ remainder is characterised by "pseudo-components". Occasionally a complete analysis is known up to C11. Rarely, but occasionally, a 'full' compositional analysis undertaken; in this case mass spectrometry could identify families, at least, of compounds. Such resolution can be important to lubricants manufacture in particular. The more usual characterization procedure is to measure the boiling range distribution of crude oil as the cumulative amount distilled versus temperature and then to splice the resulting S-shaped curve into a number of histogram-type intervals, each one representing a pseudo component which is a hypothetical hydrocarbon of certain normal boiling point and containing an amount of material determined by the splicing regime. The boiling temperature of a pseudo-component is the volumetric average temperature for the particular histogram interval. A corresponding curve can be measured for density distribution. Typically, even the best laboratory instruments, chromatograph or distillation apparatus, cannot measure boiling points much above 550C, yet a significant fraction of crude oil boils at higher temperatures and the final boiling point is uncertain. This introduces a complicating factor for characterization, and the 'end point' is assumed to be 800+C.

The basic properties (normal boiling point, density, molecular weight) of light hydrocarbons are essentially those of the pure compounds. For heavier hydrocarbons, characterised by pseudo-components, the boiling point and density are obtained as described above and molecular weight is predicted as a function of these two properties. Other correlation variants on the inter-relationships between those three properties exist as well. From these properties component criticals and acentric factor can be determined and thus the data needed by an EOS (equation of state) thermodynamic model is furnished. For the heavier end of the boiling range there is uncertainty associated with molecular weight since any attempt to measure high boilers in conventional apparatus would result in their thermal decomposition. For this reason vapour pressure type thermodynamic methods are sometimes used to predict K-values for refinery separations involving such material, as opposed to customary EOS methods. Vapour pressure can be correlated from basic physical properties and is supported by measurement. In high pressure oil production applications the uncertainty in the component criticals is taken as justification for using them as tuning parameters to reproduce field Gas/Oil ratios (i.e. VLE or VLLE).

To conclude, the manner by which hydrocarbon feedstock is characterised so as to be recognisable to flowsheeting packages makes a unique demand not only on the properties handling aspect of a simulator but also on how feed flowrate is specified i.e. in terms of whole oil (bulk substance) rather than directly in terms of individual constituent pseudo-component flowrates. The characterization procedure outlined above assigns an appropriate amount of the 'whole' to each pseudo-component.

1.1.2 Special Petroleum Properties

In addition to the basic physical properties of density, molecular weight, and so on, which are essential to phase equilibrium calculations, a wide range of other properties are key quality and control indicators in practice. For refined products these include, sulphur content, flash point, Reid vapour pressure, cloud point, freeze point, refractive index, nickel content, vanadium content, Conradson carbon and toxicity parameters. The properties referred to as 'special', here, are variously known as refinery properties, petroleum properties, qualities, cold properties and inspection properties: there are standard procedures for their measurement and they are reported in a typical oil assay. Such properties are not predictable, either from basic physical properties or from molecular structure. Any one pseudo-component will comprise many different compounds (paraffins, naphthenes, olefins and aromatics). If sufficient data points are available to form a curve (covering the boiling range) for a given property such as sulphur content, values can be assigned to each pseudo in a manner analogous to the boiling curves already described. The value of any given petroleum property for a flowsheet stream is determined according to an empirical mixing rule applied to all of the contributions from the various pseudo components in that stream. Several of the properties mentioned above demand mixing rules which are very non-linear in form and are frequently proprietary.

These properties are tracked throughout processes for a variety of reasons e.g. cloud point may be a control point for a distillation product streams, metals content which are catalyst poisons is required by reactor models and other properties such as sulphur and cetane number must be known for product quality control.

1.2 Flowsheet Simulation

1.2.1 Common

For distillation, at least, of crude oil, thermodynamic representation is straightforward even though the characterization of the material is not straightforward. For instance, several feeds each represented by a C6+ fraction may be present in any one simulation e.g. if a number of different oils are present. As a consequence there could be more than one pseudo-component of identical boiling point but differing in all other properties, most particularly density. By convention each pseudo-component has an invented name which contains the normal boiling point number for easy recognition e.g. NBP-120. Clearly, if a component list has two or more pseudos with the same boiling point and different properties, the system has to manage that eventuality; producing unique names may be one approach. Procedures for mathematically combining oils or oil fractions into a single blend of consolidated boiling curve, density curve and so on, with a consequent breakdown into a single set of pseudos is common practice. Significantly, this step is performed before solving the flowsheet proper. However, if the requirement is to retain in a flowsheet the identity of each constituent oil then there seems no simple way around characterising each one separately and introducing as many corresponding sets of pseudos as there are oils to the simulation. This is entirely achievable in commercial simulators today but at a price which challenges practicality. The number of components in the component list would run to many hundreds or even thousands (for a refinery), which adversely affects, at a minimum, the run time performance.

A component list must be capable of dealing with the entire oil, or oil blend, as a single 'macro component' as far as defining total flowrate is concerned, yet must also break this down into pseudo-components.

1.2.2 Oil Refining

Distillation is adequately modelled using the pseudo-component approach for the characterization of oil blends or oil fractions. However, pseudo-components pose difficulties for modelling extraction and certain reaction processes. Component distribution coefficients describing a liquid-liquid extraction process would most commonly be determined by a liquid activity model. But, activity coefficients for pseudo-components of unknown molecular structure are indeterminate. For reaction processes too, pseudo-components have their limitations: formal reactions cannot be expressed, elemental balance may be compromised and heat of reaction is not readily predictable since heat of formation is uncertain.

The modelling of refinery reactors is relatively straightforward for light-ends processes and relatively complex for heavy-ends processes. Reactors which deal with light feeds (C6-), which include alkylation, isomerisation, MTBE, Catalytic polymerisation processes and so on can be approached in the same way as for any other chemical process. Property data of the actual compounds is available from data banks, the reactions are known, the stoichiometry is known and the kinetics/equilibrium are generally well known. Simulator architectures cater for this general requirement already, even if the specification of proprietary kinetics is simulator-specific.

Catalytic Reforming processes handle slightly heavier feeds (naphtha) but, as earlier, the chemistry is well known. Typically, xx components and yy reactions might be required. The challenge for this type of reaction model is that the upstream simulated feed to the reactor may be characterised by pseudo-components (plus Paraffinic Olefinic Naphthenic Aromatic breakdown) so a way is needed to 'map' the boiling curve onto the xx components. These components may be internal to the reactor UO and not appear elsewhere in the flowsheet.

Refinery conversion processes convert high boiling material into more valuable light products such as gasoline and diesel, and for these the chemistry is complex and fundamental models are a rarity. There are two categories of conversion process: catalytic and thermal. Fluidised catalytic cracking (FCC), hydrocracking and residue cracking are of the catalytic type whereas visbreaking and coking are thermal-type. Either way, a semi-empirical approach is common combining limited theory with plant data to produce statistical models employing tuning factors. One such factor may account for catalyst de-activation, for instance. Commercial software for these reactor types does exist for the individual units; their implementation in flowsheet simulation is rare.

Purification processes, e.g. de-sulphurisation, treat the particular hydrocarbon fraction with gaseous hydrogen at elevated pressure, over catalyst, and the particular process may be vapour-phase or two-phase. These are kinetic processes for which semi-empirical methods are usually adopted.

The common thread in the fore-mentioned processes is that feed to a conversion or purification unit will be, in flowsheeting terms, a stream comprising pseudo-components. Possibilities, of varying acceptability, for defining the product streams for the particular reactor model include:

- *Inlet is described by a given set of pseudo-component properties; outlet is determined the same pseudo-component properties.* The amount of material in each pseudo in the effluent is determined by the reactor algorithm. Since these processes are known to change both the basic and the petroleum properties of the material, the effluent properties assigned to the outlet stream will be inaccurate. For instance, across a visbreaker, or even a milder reactor such as a hydrotreater, there is only a slight shift in boiling range from inlet to outlet but the accompanying shift in density curve is marked.
- *Inlet is described by a given set of pseudo-component properties; outlet is described by a different set of pseudo-component properties.* A severe limitation of most conventional commercial simulators is that a second set of pseudos, which will carry the effluent, must be defined a priori (before the simulation starts) and, being of fixed properties, will not change with reactor operating conditions. The simulator carries both sets of pseudos throughout the flowsheet. The reactor algorithm 'fills' the second set of pseudos perhaps by applying fixed yields (derived from plant measurement). The combined component list is obviously much longer than for the previous scenario, even though there may be almost complete overlap between the two sets of pseudos as a consequence of a small shift in boiling range between inlet and outlet. This is computationally inefficient as it affects the solution time for all other unit operations in the flowsheet.
- *Inlet is described by a given set of pseudo-component properties; outlet is determined by the same pseudo-component properties and internally the reactor model 'maps' pseudos to real chemical compounds.* In this instance the reactor model applies a formal chemistry to the reaction. The real chemical compounds could be purely internal to the

reactor model. The effluent stream can easily be constituted back into pseudo components for feeding downstream processes.

- *Inlet is described by a given set of pseudo-component properties; outlet is determined by the 'dynamically' revised pseudo-component properties.* This represents an ideal whereby all properties of each pseudo-component (basic and petroleum), other than boiling point, are updated by the reactor algorithm. Such a solution introduces the concept of stream-dependent component properties.

2. Requirements

2.1 Textual requirements

Petroleum fractions are generated from petroleum assay. Petroleum assay data are generally available in standard form such as ASTM D86 or True Boiling Point (TBP) analysis. The data are in the form of percent boiled off versus temperature. Given these data and other information such as bulk specific gravity (or curve), and bulk molecular weight (or curve), petroleum fractions can be generated. Each petroleum fraction will have assigned to it a molecular weight, specific gravity and boiling temperature. From these basic data, other characterization parameters and properties such as critical properties (TC, PC, VC, ZC), ideal gas heat capacity, vapor pressure, and liquid viscosity can be estimated from industry standard correlation such as the Lee-Kesler or Riazi-Daubert methods. In general, these characterization parameters and properties do not change in the course of the simulation. From the property-model point of view, petroleum fractions are the same as real components, such as methane or water. Note that the methods used to estimate these characterization parameters can be traced using the reporting functions of the Property System.

There is another class of properties associated with petroleum assay: curves of properties such as Reid vapor pressure, carbon content, viscosity, various metal contents, cloud point, and so on. The curves of properties are normally given as a function of percent boiled off or temperature. Each curve property for a given petroleum assay can be broken down (sliced) in the same way as the Assay D86 or TBP data; with a property value associated with a corresponding petroleum fraction. These properties, if not changed during the course of the calculations, are not any different from the characterization parameters TC, PC, etc discussed in the previous paragraph.

However, these properties assigned to a petroleum fraction can change during the flowsheet calculations, when, for example, the components undergo chemical reactions in a reactor block. The sulfur contents may be changed in a desulfurization unit. In fact, a reactor model can also alter the molecular weight or specific gravity of a given petroleum fraction. As a result, the petroleum fraction will also need to be re-characterized. (Note that when the petroleum fraction is re-characterized, the methods used to estimate the property and parameters of the fraction will not be changed).

When the characterization parameters and petroleum properties of a petroleum fraction are changed, the petroleum fraction essentially becomes a new species (component). In other words, the reactor generates a new set of petroleum fractions. The characterization parameters and curve properties of these new fractions must be determined. If the reactor is within a recycle loop, properties of these fractions must be continually updated.

It is evident that new interfaces are required to update characterization parameters and curve properties for petroleum fractions.

The CAPE-OPEN material template contains the component (species) information. To handle petroleum assay and fraction, the material template should be extended to include assay and fractions. To allow tracking of petroleum properties as the petroleum fractions go through the flowsheet from one Units model to another (and may change in the Reactor model), the material template should be extended to include the petroleum properties as attributes.

Another problem related to assays and petroleum fractions is one of lumping and de-lumping. It is computationally expensive to deal with a large number of components. In petroleum refining, it is not unusual to have 50 to 100 petroleum fractions. It is desirable to reduce the number of components without sacrificing the calculation accuracy. There are available methods to lump petroleum fractions into a smaller set of fractions and vice versa. Interfaces are required for these features.

2.1.1 Summary of requirements and new interfaces for petroleum assay and fractions

- **R1. New properties** such as Reid vapor pressure, cloud point. Define the complete list of properties.
- **R2. Material Template** extension to include component type to allow handling of assays and petroleum fractions.
 - Define the list of component types: real neutral component, ions, assay, petroleum fraction, polymer, etc.
- **R3. Material Template** extension to include petroleum properties as attributes.
- **R4. New Interface to re-characterize pseudo component parameters.**
 - Method for number of petroleum components.
 - Method for updating characterization parameters for a given set of petroleum components
- **R5. New Interface to update petroleum properties.**
 - Method for number of petroleum properties.
 - Method for number of petroleum components and real components.
 - Method for updating petroleum property.
 - Method for copying petroleum property
- **R6. New Interface to lump petroleum fractions** into smaller set of fractions (including the corresponding characterization parameters and curve properties)
- **R7. Interface to de-lump petroleum fractions** into its original set of fractions.

2.1.2 Summary of requirements that will be fulfilled with the proposed interfaces

- **R1. New properties** *are included*
- **R2. Material Template.** extension to include component type to allow handling of assays and petroleum fractions.

This will be done by modifying the THRM interface ICapeThermoPropertyPackage

- **R3. Material Template** extension to include petroleum properties as attributes.

These will all be included in the Material Object

- **R4. New Interface to re-characterize pseudo component parameters.**
 - Method for number of petroleum components.

This is implicit in the qualifiers of the pseudo components; i.e. the sum of components with the qualifier PetroleumFraction will be the number of petroleum components

- Method for updating characterization parameters for a given set of petroleum components.

New interface will be required for the Property Packages (see “Requirements form other Packages”)

- **R5. New Interface to update petroleum properties.**
 - Method for number of petroleum properties.

Not supported

- Method for number of petroleum components and real components.

Implicit in the component qualifiers

- Method for updating petroleum property.

Supported

- Method for copying petroleum property

Supported

- **R6. New Interface to lump petroleum fractions** into smaller set of fractions (including the corresponding characterization parameters and curve properties)

Not supported

- **R7. Interface to de-lump petroleum fractions** into its original set of fractions.

Not supported

2.2 Uses cases

2.2.1 Actors

- ❑ **Flowsheet Builder.** The person who sets up the flowsheet, the structure of the flowsheet, chooses thermo models and the unit operation models that are in the flowsheet. This person hands over a working flowsheet to the Flowsheet User. The Flowsheet Builder can act as a Flowsheet User.
- ❑ **Simulator Executive.** The part of a simulator whose job it is to create, or load, a previously stored flowsheet, solve it and display the results.
- ❑ **Refinery UNIT (REF-UNIT).** A CAPE-OPEN Unit Operation requiring petroleum fractions recharacterization procedures. These are typically reactor operations and blenders/mixers.

2.2.2 List of Use Cases

- ❑ UC-001 Add REF-UNIT to Flowsheet
- ❑ UC-002 Specify REF UNIT's Material Connections
- ❑ UC-003 REF-UNIT Gets Petro Props from Inlet Material Connections
- ❑ UC-004 REF-UNITs Sets Petro Props in Outlet Material Connections.
- ❑ UC-005 REF-UNIT Defines Outlet Material Objects from Inlet Material Objects.
- ❑ UC-006 Evaluate REF-UNIT.

2.2.3 Use Cases Maps

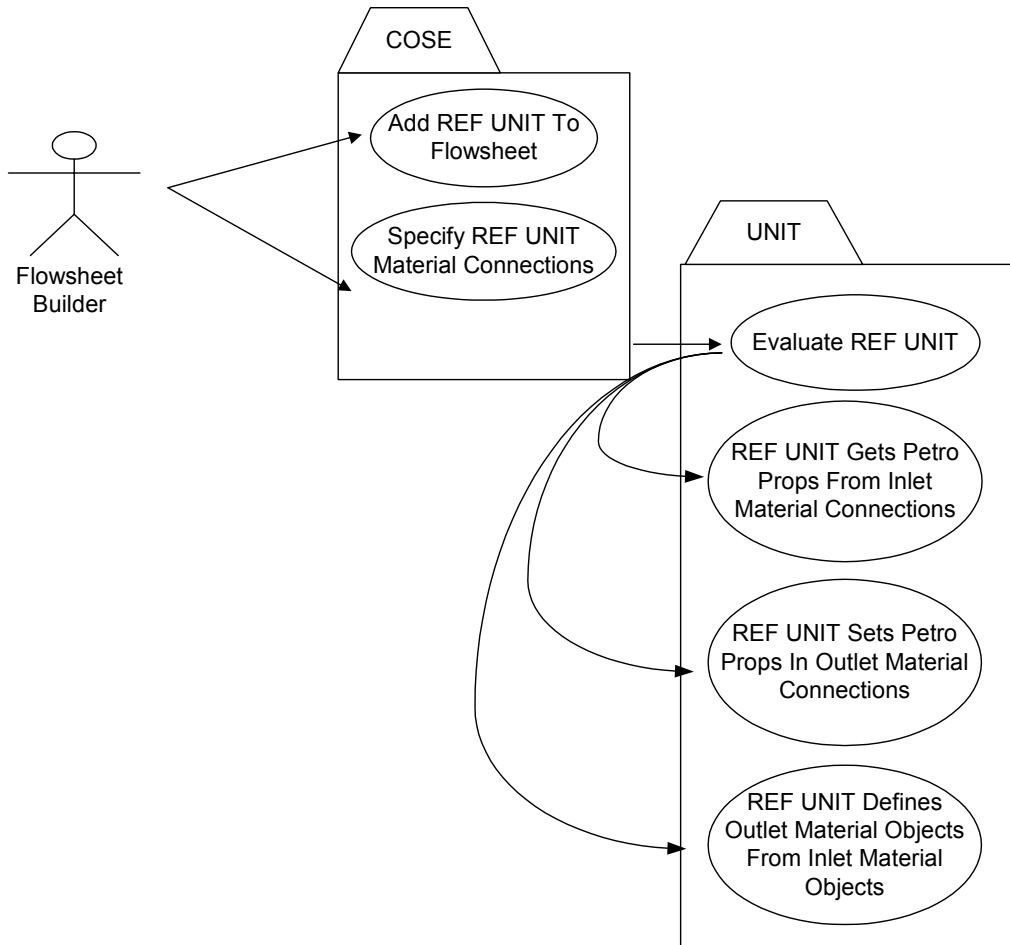


Figure 1 Use-Cases map

2.2.4 Use Cases

UC-001 ADD REF-UNIT TO FLOWSHEET

Actors: Flowsheet Builder

Priority: As in UNIT Use Case Add UNIT to Flowsheet

Classification:

Context:

Pre-conditions: As in UNIT Use Case Add UNIT to Flowsheet

Flow of events:

As in UNIT Use Case Add UNIT to Flowsheet, but the UNIT is a Refinery UNIT.

And:

The Simulator Executive asks the UNIT is it is a Refinery UNIT (i.e. requires petroleum fraction properties)

If so, the Simulator Executive will ask the UNIT if it requires re-characterization of petroleum fraction properties (see note below).

Note:

Typically, a Simulator Executive not aware of “component continuous properties” (SIM_A) will need duplicating the component slate in the outlets to “emulate” continuous properties, while in a Simulator Executive able to cope with “component continuous properties” (SIM_B) this is not required.

In both cases (SIM_A and SIM_B) the UNIT will be presented with a single component slate, and therefore, for a UNIT there will be no difference regarding the capabilities of the Simulator Executive.

SIM_A will have a set of pseudo components in the inlets (e.g. HYP_GROUP_1) and two sets of pseudo components in the outlets (e.g. HYP_GROUP_1 and HYP_GROUP_2). Flow rates of HYP_GROUP_1 in the outlets will be all zero, since UNIT results will be in fact represented in HYP_GROUP_2.

To emulate continuous properties (from the perspective of a UNIT), SIM_A will have to clone outlets, and remove the additional component slate HYP_GROUP_2. The cloned outlet will be the one presented to the UNIT (i.e. contain a single component slate, e.g. HYP_GROUP)

When the UNIT operates on outlet hypo group (HYP_GROUP), SIM_A will know these operations have to actually be performed on HYP_GROUP_2 and not on HYP_GROUP_1.

Post-conditions:

As in UNIT Use Case Add UNIT to Flowsheet.

Errors:

As in UNIT Use Case Add UNIT to Flowsheet

Uses:

Extends: UNIT Use Case <Add UNIT to Flowsheet>

UC-002 SPECIFY REF-UNIT'S MATERIAL CONNECTIONS

Actors: Flowsheet Builder

Priority: As in UNIT Use Case Specify UNIT's Material Connections

Classification:

Context:

Pre-conditions: As in UNIT Use Case Specify UNIT's Material Connections

Flow of events:

As in UNIT Use Case Specify UNIT's Material Connections, but the UNIT is a Refinery UNIT.

And:

The UNIT will check that the connected Material Object supports petroleum fractions.

Post-conditions:

As in UNIT Use Case Specify UNIT's Material Connections.

Errors:

As in UNIT Use Case Specify UNIT's Material Connections

And: the connected Material Object does not support petroleum fractions.

Uses:

Extends: UNIT Use Case <Specify UNIT's Material Connections>

UC- 003 REF-UNIT GETS PETRO PROPS FROM INLET MATERIAL CONNECTIONS

Actors: REF UNIT

Priority: High

Classification:

Context:

Pre-conditions:

The UNIT has indicated to the Simulator Executive that it is a REF UNIT. Thus the Simulator Executive can prepare its Material Objects appropriately.

Flow of events:

As in the UNIT Use Case <Get Input Material Streams From Input Ports>, but the information to gather is now concerning Petroleum Fractions, thus:

The UNIT connects with the part of its inlet Material Object that carries Petroleum Fraction properties

The UNIT requests certain "PetroFrac" properties. These properties can correspond to:

A) A particular "PetroFrac" pseudo component (e.g. molecular weight, density, NBP, etc), in which case the UNIT will supply the identifiers of the components whose properties are to be retrieved.

B) The whole PetroFracs (e.g. single properties such as PourPoint, FlashPoint, etc, or curve properties such as TBPCurve)

Post-conditions:

The UNIT is delivered with the requested property.

Errors:

The property does not exist as specified by the REF UNIT

Uses:

Extends: UNIT Use Case <Get Input Material Streams From Input Ports>

UC- 004 REF-UNIT SETS PETRO PROPS IN OUTLET MATERIAL CONNECTIONS

Actors: REF UNIT

Priority: High

Classification:

Context:

Pre-conditions:

The UNIT has indicated to the Simulator Executive that it is a REF UNIT. Thus the Simulator Executive can prepare its Material Objects appropriately.

Flow of events:

As in the UNIT Use Case <Set Output Material Streams Through Ports>, but the information to set is now concerning Petroleum Fractions, thus:

The UNIT connects with the part of its outlet Material Object that carries Petroleum Fraction properties

The UNIT tries setting certain “PetroFrac” properties. These properties can correspond to:

A) A particular “PetroFrac” pseudo component (e.g. molecular weight, density, NBP, etc), in which case the UNIT will supply the identifiers of the components whose properties are to be retrieved.

B) The whole PetroFracs (e.g. single properties such as PourPoint, FlashPoint, etc, or curve properties such as TBPCurve)

The UNIT tries re-characterising the newly specified Outlet Material Stream

The Simulator Executive will perform a recharacterization based on the supplied properties.

Post-conditions:

The properties provided by the UNIT are accepted by the outlet material object

Re-characterization of the outlet material/s object/s proceeds successfully

Errors:

Re-characterization fails (i.e. the available methods for characterising the pseudo components can not process the newly specified petro properties)

Uses:

Extends: UNIT Use Case <Set Output Material Streams Through Ports>

UC- 005 REF-UNIT DEFINES OUTLET MATERIAL OBJECTS FROM INLET MATERIAL OBJECTS

Actors: REF UNIT

Priority: High

Classification:

Context:

Pre-conditions:

The UNIT has indicated to the Simulator Executive that it is a REF UNIT. Thus the Simulator Executive can prepare its Material Objects appropriately.

Flow of events:

UNIT gets Input Material Objects and Outlet Material Objects

UNIT requests Outlet Material Object to be specified as the Inlet Material Object (i.e. copy inlet to outlet)

UNIT requests from the Simulator to Recharacterise the outlet.

Post-conditions:

The properties provided by the UNIT are accepted by the outlet material object

Re-characterization of the outlet material/s object/s proceeds successfully

Errors:

Re-characterization fails (i.e. the available methods for characterising the pseudo components can not process the newly specified petro properties)

Uses:

Extends: UNIT Use Case <Set Output Material Streams Through Ports>

UC- 006 EVALUATE REF-UNIT

Actors: Simulator Executive

Priority: High

Classification:

Context:

Pre-conditions:

As in UNIT Use Case Evaluate UNIT.

Flow of events:

As in UNIT Use Case Evaluate UNIT, but the target UNIT is a Refinery UNIT.

Post-conditions:

As in UNIT Use Case Evaluate UNIT.

Errors:

As in UNIT Use Case Evaluate UNIT.

Uses:

Extends: UNIT Use Case <Evaluate UNIT>

2.3 Sequence Diagrams

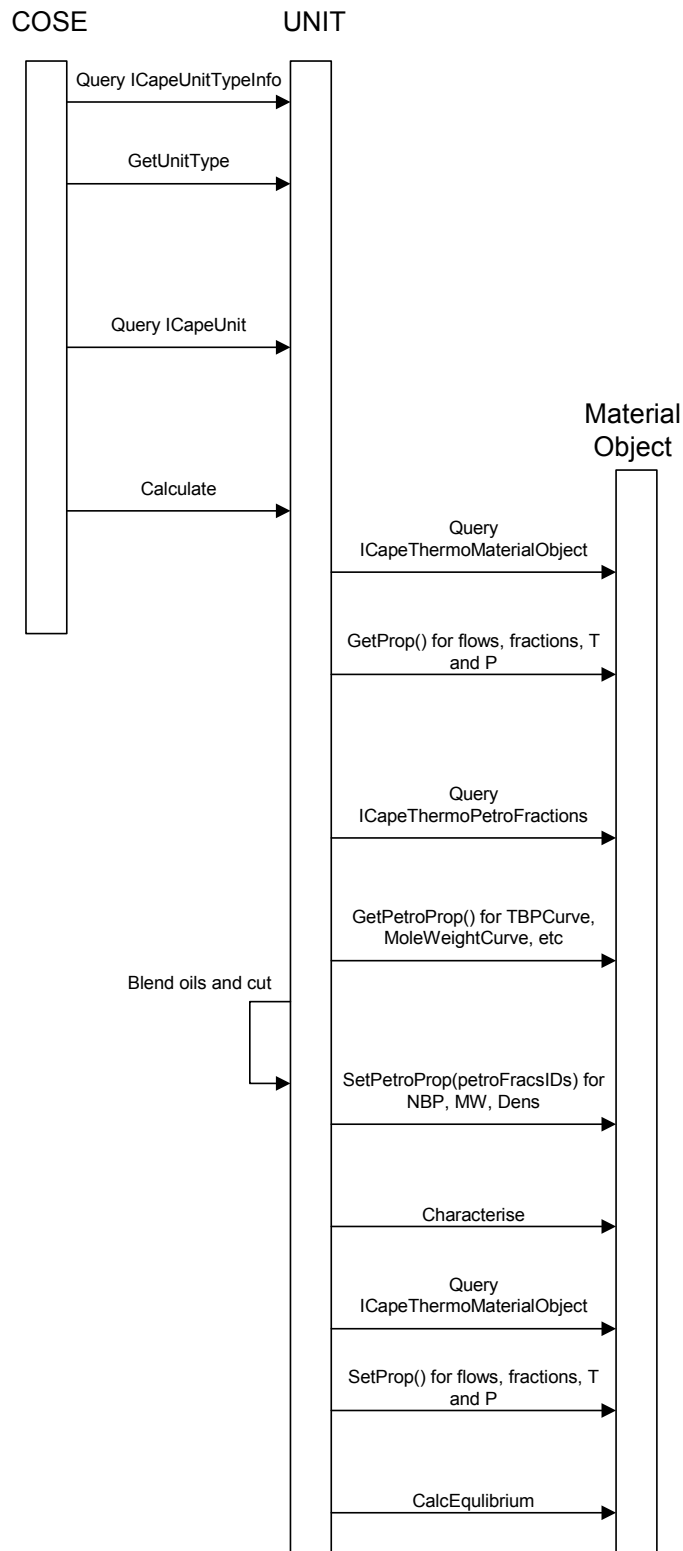


Figure 2 Main sequence diagram

3. Analysis and Design

3.1 Overview

3.2 Sequence diagrams

3.3 Interface diagrams

The interface ICapeThermoPetroFractions will be implemented on the Material Object, as the interface ICapeThermoMaterialObject is, and will serve for Refinery Unit Operation to access petroleum fraction properties.

IN-001 INTERFACE DIAGRAM

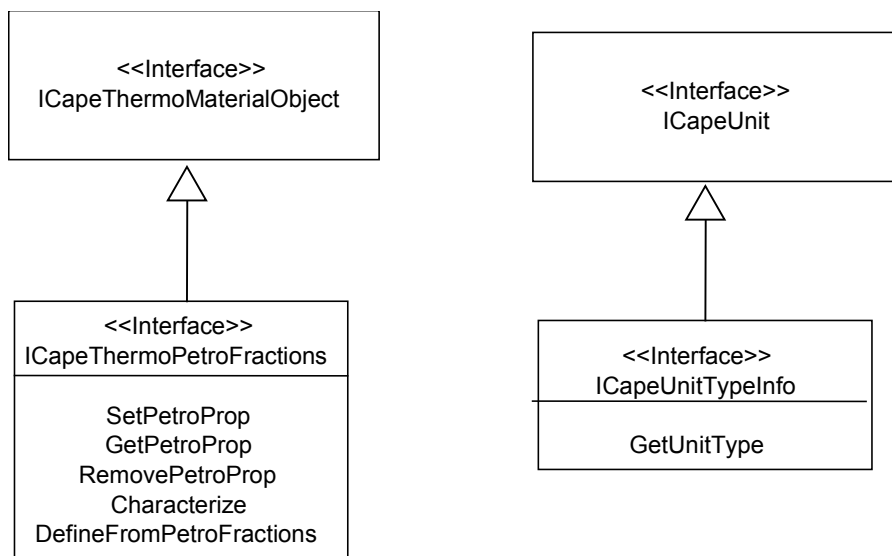


Figure 3 Interface diagram

The interface ICapeUnitTypeInfo will be implemented on the UNIT and will give the Simulator Executive information on the type of Unit Operations; more specifically the simulator will need to know if the operation is a refinery reactor, an oil blender, other refinery operation different from the first two, or any other regular unit operation.

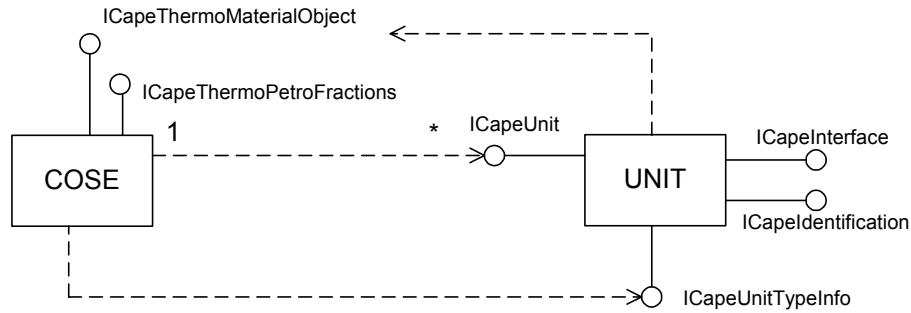
Although the interface ICapeUnitTypeInfo is specifically defined for the Simulator to know that a refinery operation has been inserted in the flowsheet, this interface can be used to provide a classification of any type of Unit Operation.

3.4 State diagrams

3.5 Other diagrams

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CO-001 COMPONENTS DIAGRAM



3.6 Interfaces Description

The interface proposed to cover the Use Cases presented above is named ICapeThermoPetroFractions.

Following solutions proposed in CAPE-OPEN for similar functionalities, e.g. ICapeThermoMaterialObject, the interface ICapeThermoPetroFractions is designed as a properties container. Since it is not reasonable to assume the operating procedures and functionality of every refinery operation, the interface and the underlying calling patterns (as it will be shown later) do not impose any restriction regarding the amount and type of properties a refinery operation requires/provides from/to the hosting simulation environment.

Thus, certain operations like blenders may need the distillation curve of the inlet crude, plus some bulk properties to generate the blended outlet. Others, such as reactors, may need the complete pseudo component slate and their associated component parameters.

The Simulator Executive will provide the inlet Material Objects with as much information as it can (e.g. complete characterised component slate, distillation curves, bulk properties, etc). The Refinery Operation will provide as much information as it can to its outlet Material Objects, and will request from the Simulator Executive to complete re-characterization.

3.6.1 ICapeThermoPetroFractions

Interface Name	ICapeThermoPetroFractions
Method Name	SetPetroProp
Returns	--

Description

Sets characterization properties for individual petroleum fractions and for the complete set of petroleum fractions (in the form of bulk properties and curves)

Arguments

Name	Type	Description
[in] propertyID	CapeString	Characterization property to set (see Tables 7.1 and 7.2)
[in] compID	CapeArrayString	Component whose characterization property is to be updated. If compID is NULL, it means the property applies to all petro fractions (bulk prop or characterization curve)
[in] basis	CapeString	Calculation basis for the petroleum property (e.g. mass, mole, volume). Expansion of the currently available THRM basis qualifier. This includes volume
[in] values	CapeArrayDouble	Value of the property. If compID is provided the property to be set will be an individual value stored in the first position of the array. If compID is not specified, then the property to be set is a curve property for all the fractions, and the value will be an array

Errors

ECapeUnknown, ECapeInvalidArgument

Interface Name	ICapeThermoPetroFractions
Method Name	GetPetroProp
Returns	CapeArrayDouble

Description

Gets characterization properties for individual petroleum fractions and for the complete set of petroleum fractions (in the form of bulk properties and curves).

It returns the value of the property. If compID is provided, it will return an individual value stored in the first position of the array. If compID is not specified, it will return a curve property for all the fractions, and the value will be an array.

Arguments

Name	Type	Description
[in] propertyID	CapeString	Characterization property to set.
[in] compID	CapeArrayString	Component whose characterization property is to be updated. If compID is NULL, it means the property applies to all petro fractions (bulk prop or characterization curve)
[in] basis	CapeString	Calculation basis for the petroleum property (e.g. mass, mole, volume)

Errors

ECapeUnknown, ECapeInvalidArgument

Interface Name	ICapeThermoPetroFractions
Method Name	Characterize
Returns	--

Description

Re-characterizes the set of petroleum fractions with the currently available set of characterization properties.

Arguments

None

Errors:

ECapeUnknown, ECapeSolvingError, ECapeComputation, ECapeLicenseError, ECapeOutOfResources

Interface Name	ICapeThermoPetroFractions
Method Name	RemovePetroProp
Returns	--

Description

Removes any existing characterization properties for individual petroleum fractions and for the complete set of petroleum fractions (in the form of bulk properties and curves)

Arguments

Name	Type	Description
[in] propertyID	CapeString	Characterization property to removed. If a property is removed it will not be taken into account for recharacterization.
[in] compID	CapeArrayString	Component whose characterization property is to be removed. Set this to NULL for a bulk property or a characterization curve

Errors

ECapeUnknown, ECapeInvalidArgument

Interface Name	ICapeThermoPetroFractions
Method Name	DefineFromPetroFractions
Returns	--

Description

Copies all petroleum properties of the origin set of petroleum properties to the target set of petroleum properties. It will be used by those operations that do not modify characterization properties, but simply pass them to the outlet.

Arguments

Name	Type	Description
[in] originFractionsSet	CapeInterface	PetroFractionsSet whose properties will be copied to this Fractions Set

Errors

ECapeUnknown, ECapeInvalidArgument

3.6.2 ICapeUnitTypeInfo

Interface Name	ICapeUnitTypeInfo
Method Name	GetUnitType
Returns	CapeUnitType

Description

Gets the type of Unit Operation. Among others, the following types should be defined:

CapeUnitType:

- ❑ CAPE_REFINERYREACTOROP,
- ❑ CAPE_REFINERYBLENDEROP,
- ❑ CAPE_REFINERYGENERALOP,
- ❑ CAPE_CONVENTIONALOP

Arguments

None

Errors

ECapeUnknown, ECapeInvalidArgument

3.7 Scenarios – Proposed Scenario to Validate the Interfaces

3.7.1 Introduction

As described in this document, the proposed interfaces support the operations of refinery units, by exposing a series of properties, characteristics of the oil industry. In this sense, the new interfaces increase the container capabilities of the Material Object.

In addition to this, the new interfaces propose a complete new behavior (i.e. re-characterization of pseudo components), that affects the functionality required from CAPE-OPEN property packages.

Thus, to support continuous updating of component properties (which is something that e.g. refinery reactors and blenders will require), a CAPE-OPEN property package, if applied to the flowsheet, has to allow its components properties to be updated during the course of the simulation. This implies modifying the set of interfaces for Thermo Property Package, and consequently enhancing the existing prototypes.

Since, from a realistic viewpoint, this will not be achievable within the remaining project period, the proposed validation scenario assumes that no CAPE-OPEN property package is applied to the flowsheet. Rather, native simulator property package will be used.

This simplification of the project does not compromise or modifies the testing of the proposed interfaces. Thus, to test the ICapeThermoPetroFractions and ICapeUnitTypeInfo interfaces, the only requirements are: 1) to have a UNIT plug, that will act as a client of ICapeThermoPetroFractions, and 2) to modify the

implementation of the Material Object to support the new interface and to provide the UNIT plug with the required petroleum properties.

The UNIT plug will need to be able to estimate pseudo component properties, but this will be achieved using simulator native characterization methods.

Although the proposed interfaces allow plugging refinery UNIT components into Simulators aware or unaware of continuous properties, the prototype will be demonstrated in a non-continuous properties simulator (e.g. HYSYS.Process).

3.7.2 Validation Scenario

The proposed prototype is an oil blender. The oil blender will accept two inlet material objects, each representing a distinct crude oil, and will produce a blended oil.

Oils in each one of the inlet MOs will be represented by a set of pseudo components (e.g. Oil_1 is represented by HypGrp_1 and Oil_2 is represented by HypGrp_2). The blended oil will be represented by a third group of pseudo components (e.g. HypGrp_3).

Each oil will carry its own cold properties, curves and component characterization parameters. These will be stored in the corresponding MOs.

The Blender Prototype will fetch the following information from the inlets:

Accessing the **ICapeThermoMaterialObject** interface:

- ❑ Number of light-end components and their corresponding molar fractions/flows
- ❑ Temperature and pressure
- ❑ Pure Component properties such as Molecular weight and liquid density

Accessing the **ICapeThermoPetroFractions** interface:

- ❑ TBPCurve for the two inlets
- ❑ CutPointCurve for the two inlets
- ❑ MassDensityCurve for the two inlets
- ❑ MoleWeightCurve for the two inlets

With this information, the blender operation will characterize a new oil based on a user specified number of cuts (i.e. pseudo components). This new set of pseudos will be stored as part of Hypo_Group_3

The blender will provide the following information on its single outlet:

Through the **ICapeThermoPetroFractions** interface:

- ❑ Normal Boiling point of each new pseudo component
- ❑ Molecular weight of each new pseudo component
- ❑ Density of each new pseudo component

Once this information has been provided, the blender will request from the outlet material object to characterize the new set of pseudo components.

The Simulator Executive will then use the specified component properties to estimate e.g. T_c , P_c , Acentric Factor, etc. The Simulator Executive will use its own characterization methods to determine these component properties.

Through the **ICapeThermoMaterialObject** interface the blender will then provide the following information:

- ❑ Mole Fractions of each new pseudo component
- ❑ Total molar flow rate of the blended oil
- ❑ Temperature and pressure

And will request from the Material Object to perform a flash operation, to complete calculations.

4. Interface Specifications

4.1 COM IDL

// You can get these intructions in PetroleumFractions.idl file from CAPE-OPENv1-0-0.zip

4.2 CORBA IDL

// You can get these intructions in CAPE-OPENv1-0-0.idl within the
CAPEOPEN100::Business::PhyProp::Thrm::Cose module and in
CAPEOPEN100::Business::UnitOp::Unit module

5. Notes on the interface specifications

5.1 Requirements from other components

- In order that reactor unit operations can work inside a COSE implementing the described ICapeThermoPetroFractions interface, it must be possible that a property package allows recharacterization of the pseudo component properties.

Therefore a new method (or better a new interface, e.g. ISupportRecharacterization) is required to update component properties like molecular weight, density, normal boiling point etc...

In addition, if the property package is provided with its own routines to characterize pseudo-components, this method will allow activating those routines.

- A new basis qualifier should be added to the THRM specification, this is “volume”. Thus, properties such as “Olefins”, “Paraffins” etc, can be obtained/get in volumetric basis, which is often required in refinery operations.
- The ICapeThermoPropertyPackage::GetComponentList method should be updated to include a new component qualifier; this is the component type. Thus, Regular, PetroleumFraction, etc, will be valid component qualifiers.

5.2 List of Petroleum Fraction/s properties

5.2.1 Set of Fractions

These are characterization properties to be applied to the whole set of petroleum fractions. Some of the are bulk properties, others a characterization curves. In the case of curves, the X-axis will represent the percent boil off (%), and it is given as a separate variable called CutPointCurve.

There are properties such as Specific Gravity and Molecular Weight that are common to regular well-defined mixtures. These will be accessed through the existing ICapeThermoMaterialObject interfaces.

PROPERTIES OF THE MIXTURE (SINGLE VALUES)

Name	Type	Description
WatsonK	Double	WatsonK
TrueVaporPressure	Double	True Vapor Pressure
ReidVaporPressure	Double	Reid Vapor Pressure
FlashPoint	Double	Flash Point
PourPoint	Double	Pour Point
CloudPoint	Double	Cloud Point
FreezePoint	Double	Freeze Point

AnilinePoint	Double	Aniline Point
APIGravity	Double	API Gravity
ViscosityAt100F	Double	Viscosity at 100 F
ViscosityAt210F	Double	Viscosity at 210 F
RefractiveIndex	Double	Refractive Index
NormalParafinsIndex	Double	NormalParafins Index
CetaneIndex	Double	Cetane Index
RON	Double	Research Octane Number
MON	Double	Motor Octane Number
Paraffins	Double	Paraffins content
Olefins	Double	Olefins content
IsoParafins	Double	IsoParafins content
Napthenes	Double	Napthenes content
Aromatics	Double	Aromatics content
MercaptanSulphur	Double	MercaptanSulphur content
Sulphur	Double	Sulphur content
Nickel	Double	Nickel content
Nitrogen	Double	Nitrogen content
Vanadium	Double	Vanadium content
ConradsonCarbon	Double	Conradson Carbon content
Asphaltenes	Double	Asphaltenes content

PROPERTIES OF THE MIXTURE (ARRAYS OF VALUES)

CutPointCurve	CapeArrayDouble	Cut Point Curve
D86Curve	CapeArrayDouble	D86 Curve

D86CorrectedCurve	CapeArrayDouble	D86 Corrected Curve
TBPCurve	CapeArrayDouble	TMP Curve
D1160VacCurve	CapeArrayDouble	D1160 Vacuum Curve
D1160AtmCurve	CapeArrayDouble	D1160 Atmospheric Curve
CriticalTemperatureCurve	CapeArrayDouble	Critical Temperature Curve
CriticalPressureCurve	CapeArrayDouble	Critical Pressure Curve
AcentricFactorCurve	CapeArrayDouble	Acentricity Factor Curve
MoleWeightCurve	CapeArrayDouble	Mole Weight Curve
SPGRCurve	CapeArrayDouble	Specific Gravity Curve
MassDensityCurve	CapeArrayDouble	Mass Density Curve
ParaffinsCurve	CapeArrayDouble	Paraffins content
OlefinsCurve	CapeArrayDouble	Olefins content
IsoParafinsCurve	CapeArrayDouble	IsoParafins content
NapthenesCurve	CapeArrayDouble	Napthenes content
AromaticsCurve	CapeArrayDouble	Aromatics content
SulphurCurve	CapeArrayDouble	Sulphur content

5.2.2 Individual Fractions

These are individual properties of each one of the petroleum fractions present in the material object

Name	Type	Description
CriticalTemperature	Double	Critical Temperature
CriticalPressure	Double	Critical Pressure
CriticalVolume	Double	Critical Volume
Acentricity	Double	Acentricity
MolecularWeight	Double	Molecular Weight
LiquidDensity	Double	Liquid Density

NormalBoilingPoint	Double	Normal Boiling Point
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6. Prototypes implementation

7. Specific Glossary Terms

8. Bibliography

8.1 Process simulation references

8.2 Computing references

8.3 General references

9. Appendices