CERTIFICATION OF APPROVAL

Conceptual Design Support Tool For Subsea Equipment Processing System

By:

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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SHAFIQ HAKIMI BIN SABRI

ABSTRACT

Conceptual design is a critical process where initial design of equipment drawing which exhibiting ideas to the stage of creating a number of alternate solutions for the designated problem. This process generates Design Concepts and the supporting analysis in order to help determines the feasibility of each of the alternative solutions. This thesis will focus on the Conceptual Design Support Tool for Subsea Processing Equipment, or known as CDST. This design tool is created with the purpose of assisting the designers. This tool is the only design tool known for supporting the oil and gas domain. In this project, the author is emphasizing on enhancing the current capability of the design tool by adding new design concepts into the design tool database. The methodology of project involves preliminary research work regarding the domains related to this project, familiarization of the support tool, a deeper study in subsea processing equipment, researching and identifying new design concepts and validating the concepts, embedding the validated concepts into the concept library, and the capability demonstration of the new enhanced design support tool. A comparison between morphology chart generated by CDSTsped and CDST are conducted in which focusing on Two-phase Separator and Three-phase Separator. A total of 24 new design concepts are embedded into the concept library. The concept variants are for both phase of separator increased dramatically from 36 to 2100 of concept variants for Two-phase Separator and from 108 to 18900 of concept variants for Three-phase Separator.

ACKNOWLEDGEMENT

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Introduction

1.1. Background of Study

Conceptual design is a preliminary process where initial design of drawing which exhibiting ideas to the stage of creating a number of alternate solutions for the designated problem. This process generates Design Concepts and the supporting analysis in order to help determines the feasibility of each of the alternative solutions. Which is why this process is also called the feasibility studies. During this stage, critical thinking and high level of creativity are required to enable the possibility of achieving a suitable or new innovation for solving the problem presented. The more the concept generated the better.

The decisions made during the stage of conceptual design have significant influence on the product cost, performance, reliability, safety and environmental effect. Among the importance of this stage is that the process helps to define the design space which may be re-examined via various iterances in the process. All details are not properly defined. There are still rooms for variation, decision and choices. In any practical situation, it is important to always get the concept design right. The concept chosen will then be the limit of the future stages in design processes. In later stages, if a designer encountered a deficiency in the concept design, little can be done to alter the concept. It has been estimated that 70-80 percent of the product costs a determined during the concept stage. Hence, it is important to remove and reduce any unnecessary and weak ideas that may be costly during the early stages of concept design.

1.2 Conceptual Design Support Tool

Conceptual Design Support Tool for subsea process equipment design (CDST) is a newly proposed design process which assimilates a systematic design approach with knowledge bases system. The purpose of the tool is to assist designers by taking over some of the monotonous activities which allows more time for the designer to focus on the creativity of the concepts. This tool is not fully automated. For the first version of CDST development, the conceptual design knowledge is focused more on subsea process equipment in the oil and gas industry.

1.3 Problem Statement

Conceptual Design Support Tool (CDST) is developed with the purpose to support and assist the process of designing any engineering system mainly on morphology chart stage. There are several areas identified that could be further modified or enhanced with the purpose of upgrading the current version of CDST. The current version of CDST has a low range of design concepts available for selection inside the Concepts Library. Thus, the CDST Concepts Library content will be enhanced with new concepts to support design process specifically for Subsea Processing System.

1.4 Objectives

The main objectives of this research will be as follows:

i. To expand and enhanced the current morphology chart capability of CDST to support Subsea Processing System design process.
ii. To demonstrate the capability of the enhanced version of CDST.

1.5 Scope of Study

With reference to the project objective, these will be the areas of scope that will be covered during the project conducted timelines:

i. Improving the content of alternate concepts inside the pre-develop concept library of the software CDST.
ii. The focus of improvement and additions of alternate concept will be on supporting the design process for Subsea Processing System.
iii. Improving the pre-develop layout or interface of the software.

Chapter 2
Conceptual Design Support Tool (CDST)

2.1 Introduction

Conceptual design is a monotonous process consisting of a series of generating and evaluating stages that gradually converge to a preferred conceptual solution. Conceptual design is known as the most critical stage in any product design process. This is the stage where all the major compositions of the product's fundamental features are decided. Other major decisions are also affected by this stages in which all the decisions are made with inadequate and imperfect information.

2.2 CDST

Conceptual Design Support Tool for subsea process equipment design (CDST) is a newly proposed design mechanism which comprehends a systematic design approach with knowledge bases system [1]. The purpose of the tool is to assist designers by taking over some of the monotonous activities which allows more time for the designer to focus on the creativity of the concepts [1]. This tool does not fully automate the conceptual design stage or substituting the human designer. For the first version of CDST development, the conceptual design knowledge is focused more on subsea processing equipment in the oil and gas industry.

In the early years, conceptual design is done manually by both experienced and in experienced designers because of lack of computer assistant tools and because of the nature of the design problems. This developed tool can help to reduce the product design time. This can be done since most of the continual and time consuming tasks are handled by the design tool. This allows the designer to utilize fully the creativity part of the design.

After a thorough research, a new conceptual design process flow model is proposed on the way how human perform the process following a systematic design approach. This model assimilates the systematic design approach with the knowledge based system. The system consist series of activities and achievements which are done and achieved through the designer's knowledge. Figure 1 shows the information relationship flow of the activities and achievement with the design knowledge-based system.

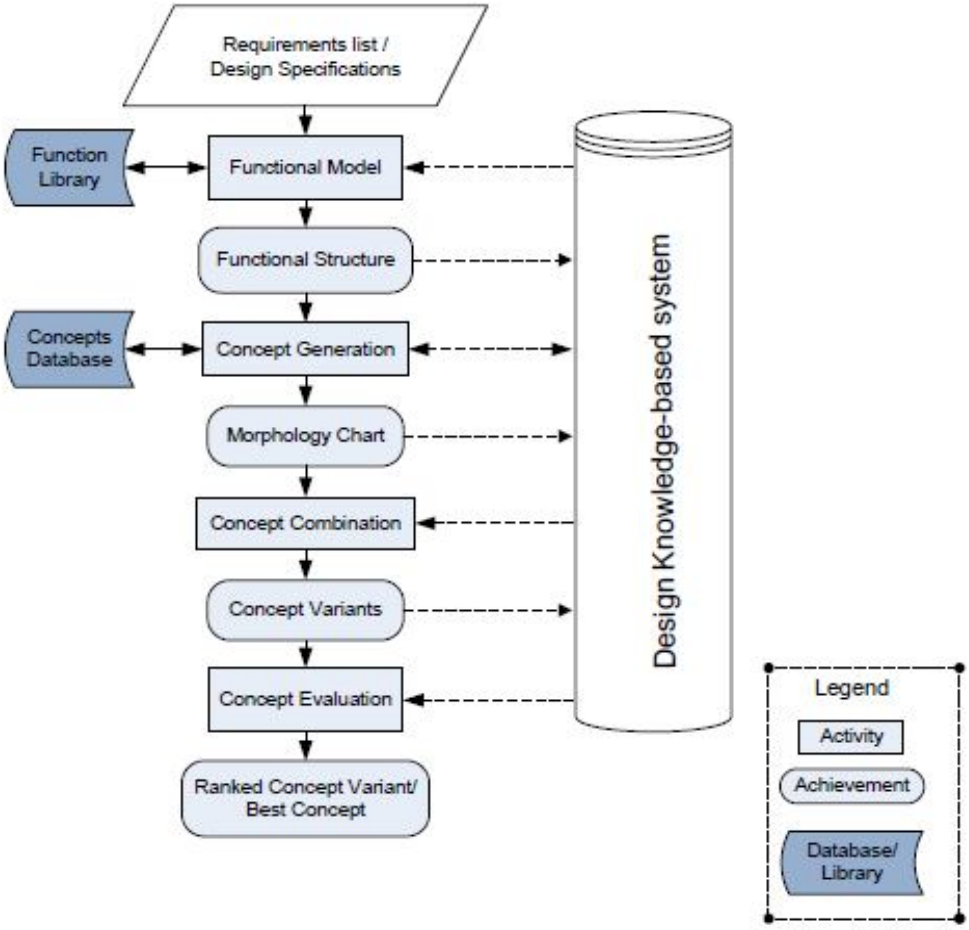


Figure 1: Conceptual Design Process Flow Model [1]

The design tool can also be used as the design knowledge management system. This is achieved by storing the design knowledge of the designers inside the tool database for future use.

2.3 Summary

Conceptual Design Support Tool, or known as CDST, is currently the only known design tool to support the oil and gas field. This design tool is still undergoing further development in order to support the oil and gas field. This tool is able to provide great assistant for designers in their pursuit to achieve the best solutions for their product design problems. This software will be the main focus tool to be used in this project, as the enhancement process will be done on the software concept library.

Chapter 3
Morphology Chart

3.1 Introduction

Morphology chart is an approach structured for expressing and identifying the relationships in the multi dimensional problems [2]. Morphology chart was developed by Fritz Zwicky in the year 1967. Fritz Zwicky was a prolific scientist and made important contributions in many areas of astronomy [3]. This method provides an approach to a concept generation phase with a wide area for pursuing the solutions for the defined engineering design problem. This method also allow the generation of ideas in analytical and systematic manner.

3.2 Morphology Chart

The morphological chart is usually applied in the beginning of the idea generation phase by taking the function analysis of the product as the starting point [4]. The chart provides a visual way to apprehend the necessary product functionality and discover alternative means and combinations in order to achieve that functionality. The chart enables these solutions to be expressed and provides a structure for considering alternative combinations.

In order to construct a functional morphological chart, the function analysis of the defined product design needs to be conducted. The features that are essentials to the product design are listed after the analysis is completed. The list should enclose the major functions at an appropriate level of generalisation. However, functions analysis does not guarantee that all the functions listed are identified. Often the solutions to these functions are already available, while the unknown need to be thought up by the designers itself.

For each of the functions that are already been discuss, a list of the possible solutions by which it might be achieved are created. This is where the creativity and innovations of the designer can take place to come up with new ideas for solutions to

the problem on hand, as well as listing all the known solutions. The possible ideas, new or known, should be expressed visually and in words. This is to provide clear understanding on how does the solution actually helps to solve the problems. The important characteristics of the solutions should be recorded for clear justification of the solutions provided.

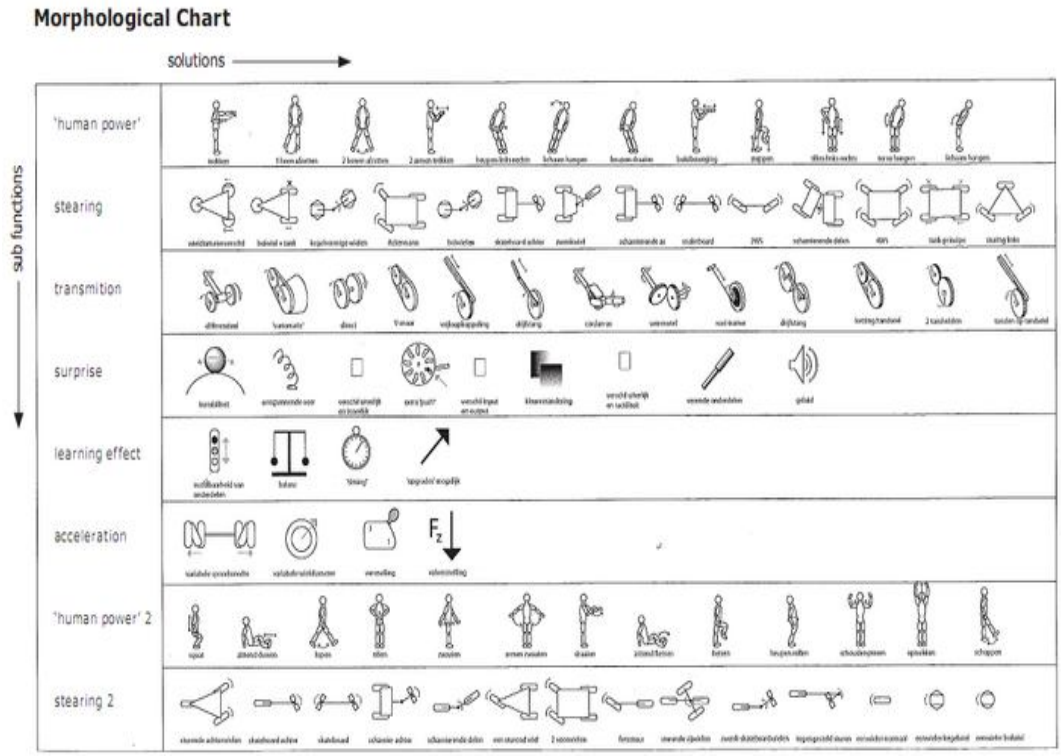


Figure 2: Example of Morphology Chart [4]

In Figure 2, the functions are listed in the left column with the possible solutions listed horizontally for each of the functions. The next step is to draw up a chart containing all the possible sub-solutions. This morphological chart should represent the total solution space for the product which is the combinations of the sub-solutions. The feasible combinations of sub-solutions are now possible to be selected and identified. The combinations of the sub-solution may be large in total, the designers may need to limit their solutions to the most feasible and attractive options for further evaluation.

3.3 Summary

Morphology chart is a crucial phase that is not suppose to be taken lightly and requires a large amount of considerations and proper evaluations in the design process. This phase help to determine the possible outcomes of the designed product, in which can give birth to various designs that possibly, suit the needs of the product. From the understanding of the main function and concept of the morphology chart, a proper process will be derived in order to enhance the morphology chart of the previous said CDST. Morphology chart is the main feature that will be focus among other features that are available inside CDST.

Chapter 4
Subsea Processing System

4.1 Introduction

Subsea is a term used to mainly on referring to the equipments, technology, and method employed in offshore oil and gas industries. This term are related to the exploration, drilling and development of oil and gas fields which is located underwater. Subsea processing holds the potential to off-load fluid equipment to the seafloor. This provides for reduction in platform/FPSO deck load requirements while also eliminating the backpressure imposed by the production riser. Subsea processing can take several forms, comprising a myriad of subsea separation and boosting scenarios. Strategic technologies that are believed to be essential for the successful implementation of subsea processing include multiphase pumping, compact separation and multiphase metering, which are all in varying stages of maturity.

4.2 Subsea Separators

Subsea separators system consists of several processing method involved in order to get the end product. The term separator in oilfield terminology designates a pressure vessel used for separating well fluids produced from oil and gas wells into gaseous and liquid components. A separator for petroleum production is a large vessel designed to separate production fluids into their constituent components of oil, gas and water. Here are the processes identified.

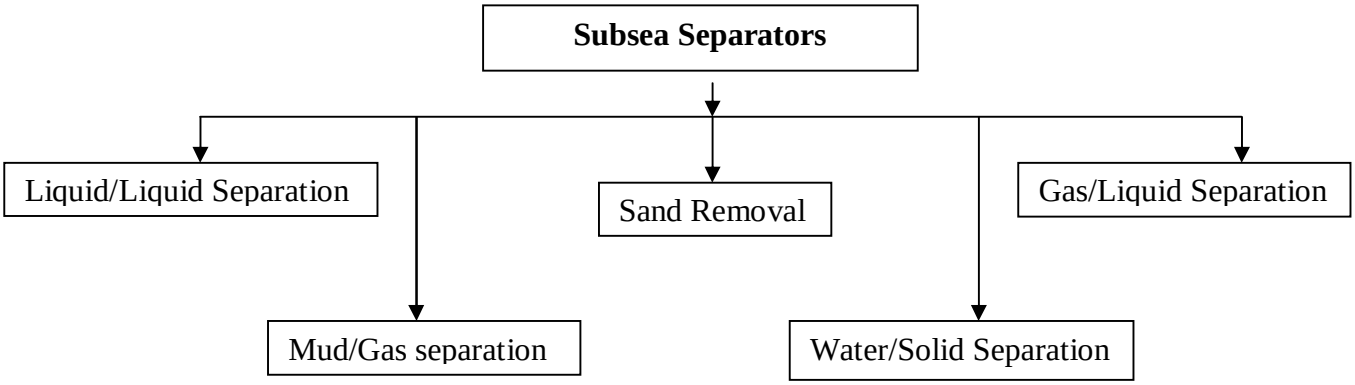


Figure 3: Subsea Separators Division

Gas – Liquid Separation: A gas–liquid separator is a device used in several industrial applications to separate a gas–liquid mixture. Separation of oil from gas may begin as the fluid flows through the producing formation into the well bore and may progressively increase through the tubing, flow lines, and surface handling equipment. Under certain conditions, the fluid may be completely separated into liquid and gas before it reaches the oil and gas separator. In such cases, the separator vessel affords only an "enlargement" to permit gas to ascend to one outlet and liquid to descend to another.

Liquid – Liquid Separation: Liquid–liquid separation, also known as solvent separation and partitioning, is a method to separate compounds based on their relative solubility in two different immiscible liquids, usually water and an organic solvent. The production of water with oil continues to be a problem for engineers and the oil producers, thus oil and water needed to be separated for further processing of the oil.

Mud – Gas Separation: Commonly called a gas-buster or poor boy degasser. It captures and separates large volume of free gas within the drilling fluid. If there is a "KICK" situation, this vessel separates the mud and the gas by allowing it to flow over baffle plates. The gas then is forced to flow through a line and vent it to a flare. The principle behind the mud gas separator is relatively simple. The mud and gas mixture is fed at the inlet allowing it to impinge on a series of baffles designed to separate gas and mud. The free gas then is moved into the flare line to reduce the

threat of toxic and hazardous gases and the mud then discharges to the shale shaker and to the tank.

Liquid – Solid Separation: The removal of water from solid material or soil by wet classification, centrifugation, filtration, or similar solid-liquid separation processes, such as removal of residual liquid from a filter cake by a filter press as part of various industrial processes.

Sand Removal: Desanders and desilters are solid control equipment with a set of hydrocyclones that separate sand and silt from the drilling fluids in drilling rigs. Desanders are installed on top of the mud tank following the shale shaker and the degasser, but before the desilter. Desander removes the abrasive solids from the drilling fluids which cannot be removed by shakers.

4.3 Summary

The rapidly accelerating shift to subsea production systems represents a significant departure from conventional operations. Subsea wells have had a good track record. However, complex subsea systems are now being deployed in ways rarely encountered in previous development schemes. These increasingly complex systems present a number of technical challenges. Thus, each subsea processing equipments are design specifically for the job that it will performs. A wide range of designs are needed in order to overcome all the challenges that this field are facing. With a good understanding of how subsea processing system work will contribute to a better finding of various design concepts of subsea processing equipment that are well known and validated in the industry.

Chapter 5
Methodology

5.1 Planned Progress Flow

This section consists of the planned progress flow for this "Conceptual Design Support Tool for Subsea Equipment Processing System" project. After the project title selection, a preliminary research work is done including consultation with the supervisor to get the overview and basic understanding of the selected project. The details and information of the project which is given by the supervisor is being studied in order to understand the project background, problem statement, objectives and scope of study for this particular project. After fully understand the basics of the project, a more thorough research work is done for the literature review of this project. During this stage, all related materials and information including the previous researches and journals are retrieved as much as possible for a more thorough and deep understanding on the subsea processing system and the equipments associates to this system.

After completing all the research works, the main stage of this project will be initiated. Firstly, in order to be able to understand the functionality of the design support tool, the software should be familiarized first. In this case, the design software which will be used is CDST because of its ability to assist designer in the early stages of system design, which is the Conceptual Generation Phase. After the CDST software has been familiarized and mastered, the next step should be to dig deeper on the configuration of the software and to focus on the alternate concept library.

Next, a thorough study and research need to be done on the Subsea Processing System. This is to ensure better understanding on the working principle of the subsea equipments. This is also to identify the main elements that need to be taken into consideration in the process of designing a subsea processing system. A datum or reference system will be chosen from the commercially available equipment. The datum then will be decomposing into physical and functional

attributes. A morphology chart will be generated from this decomposition in order to indentify the concepts that the equipment has adopted.

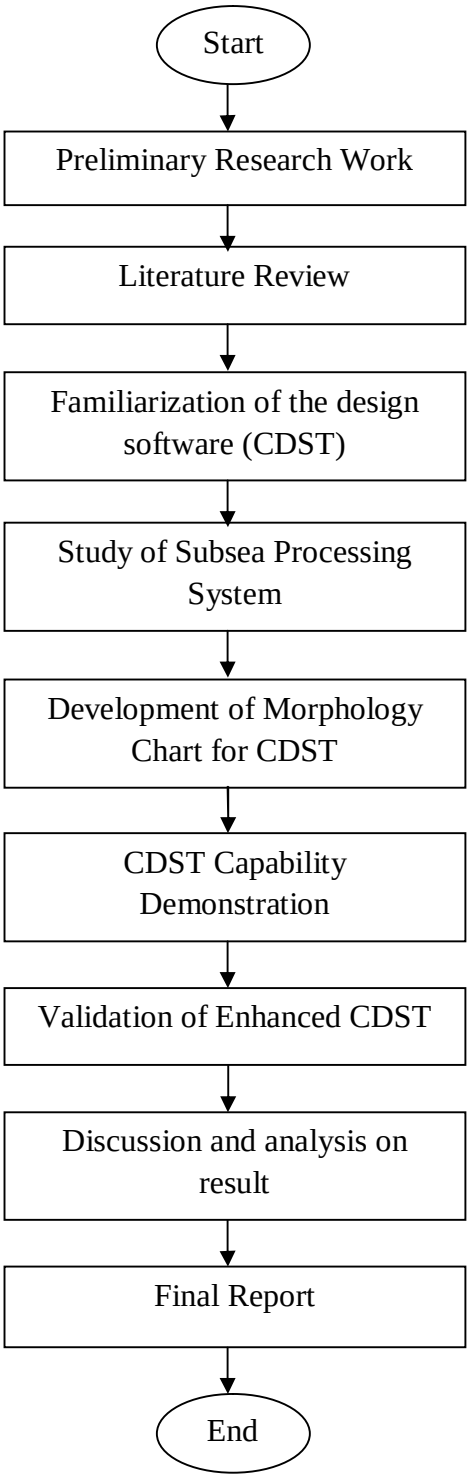


Figure 4: Project Flow Chart

The next step is the development of the morphology chart for the CDST. During this phase, a thorough understanding and study will be conducted in order to master and understood the CDST morphology chart tool box. With this study, a complete understanding of the tool box, the concepts that are already embedded into the system will be identify in order to familiarize with all the concepts and to identify which area needed to focus on enhancing. Mainly, this project will be focusing on the functions with fewer concepts available for choosing. Info and data gathering will be conducted in the process of researching a new alternate design for the focused area. The concepts that are chosen as the new alternative design will then be embedded into the system for future use.

After completing the stage of adding new concepts into the software, a demonstration will be conducted in order to prove the new capabilities of the enhanced CDST. A morphology chart will be generated by using the early version of the CDST with reference to the chosen datum in order to identify the maximum available concepts in the chart. Next, by using the enhanced CDST, a morphology chart will be generated using the same datum as reference system and the concepts that appear on the chart will be identified. The amount of concepts appear on both morphology chart will be compared.

After the demonstration phase is completed, Validation is needed in order to certify the feasibility of the new concepts embedded into the software. This phase will be then decide on how it will be conducted in order to ensure the validation process is following the standard set by active organization in charge of subsea processing system. The timeline of the planned progress flow are shown in the Research Work Schedule in Appendix 7.

5.2 Familiarization of the Design Tool

This section requires intensive understanding of the software said above, the CDST. This understanding includes of how the software works and its inner components, such as the concept library. Thus, in this section, there will be two main parts that will be considered.

The first part is the familiarization on how the software works. The first step is to understand how to input the correct verb for the overall function textually. This section is done in the Function library Window of the CDST. Next is to choose the required functional class of the equipments that corresponding to the sub-functions. Next is to choose the primary flow in which will be corresponding with the “Noun”, “Input Flow”, and “Output Flow” choices in the secondary and tertiary flows. After all the required information is properly selected, the sub-functions are saved into the working memory. The sub-functions are now available to the software for the next stage. The next step is to generate the Morphology charts of the sub-functions selected. The morphology chart will display all the available concepts that correspond to the sub-functions selected.

The next part is to identify the available concepts inside the concepts library. This stage is vital since it will determine which concepts already embedded into the library database and which concept can be embed into the database. The concepts are sorted and identify by their functions. Some of the concepts only have one function, which is their Primary Function, while some have two functions, Primary and Secondary Functions. A table contain the list of available concepts is constructed for easy identifications. The list is named “Concepts Library List”.

5.3 Development of the Morphology Chart

Development of the morphology chart is done by generating a preliminary morphology chart for the available concepts inside the concept library. For this section, a function of separator and booster are chosen to be set as the datum of the preliminary morphology chart. This is to make clear of the available concepts for the datum selected before the enhancement of the concept library database.

Five functions are primarily selected as references for the preliminary morphology charts. The functions are:-

- Separate Liquid – Gas Mixture
- Separate Liquid – Liquid Mixture
- Extract liquid Droplets
- Transfer Liquid – Gas Mixture
- Transport of Liquid

From these five functions, a preliminary morphology chart is generated. This morphology chart will serve as the “Before Enhancement” chart, and will be compared with another chart which will be generated after the enhancement of the concepts library database.

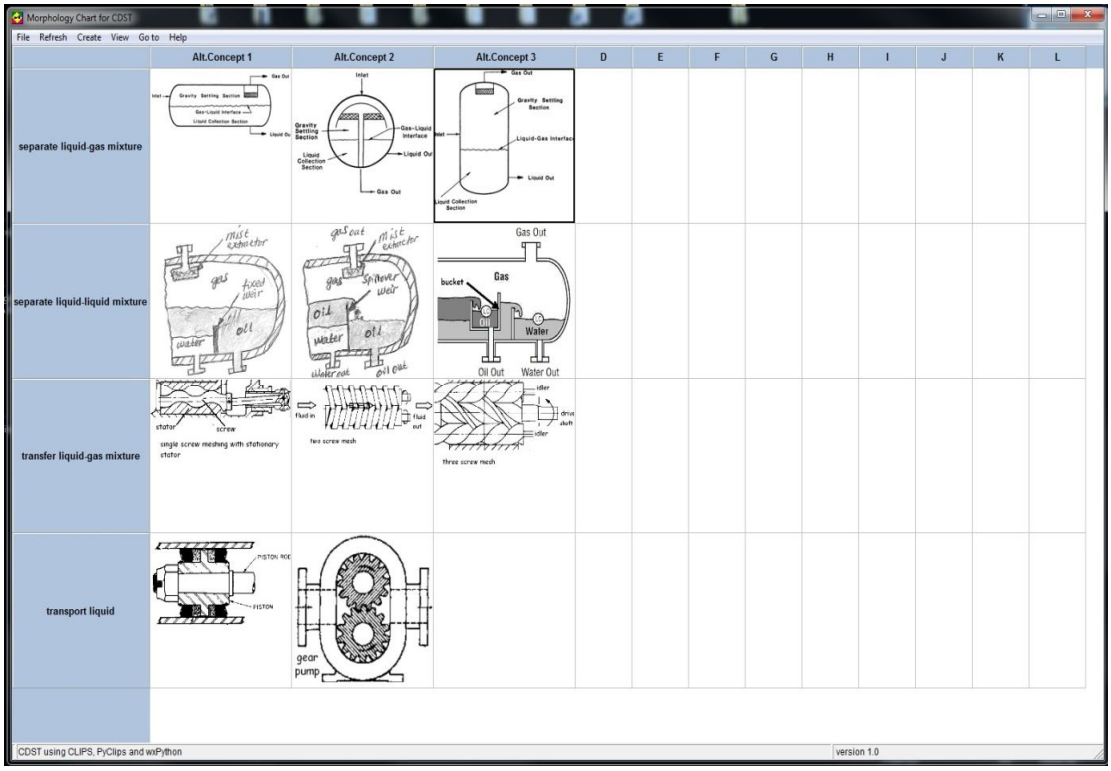


Figure 5: Snapshot of the "Before Enhancement" morphology chart – Part 1

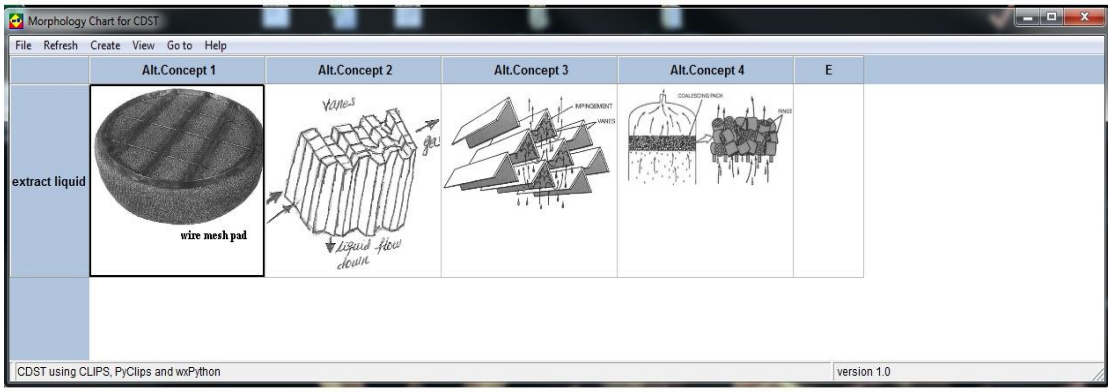


Figure 6: Snapshot of the "Before Enhancement" morphology chart – Part 2

Figure 5 and 6 shows the "Before enhancement" morphology chart generated by the software with the selected functions. This morphology chart will serve as the basis of comparison of the "Before" and "After" morphology chart. Next, a process flowchart is created in order to plan the work process and to ensure the execution of the task is perfectly done.

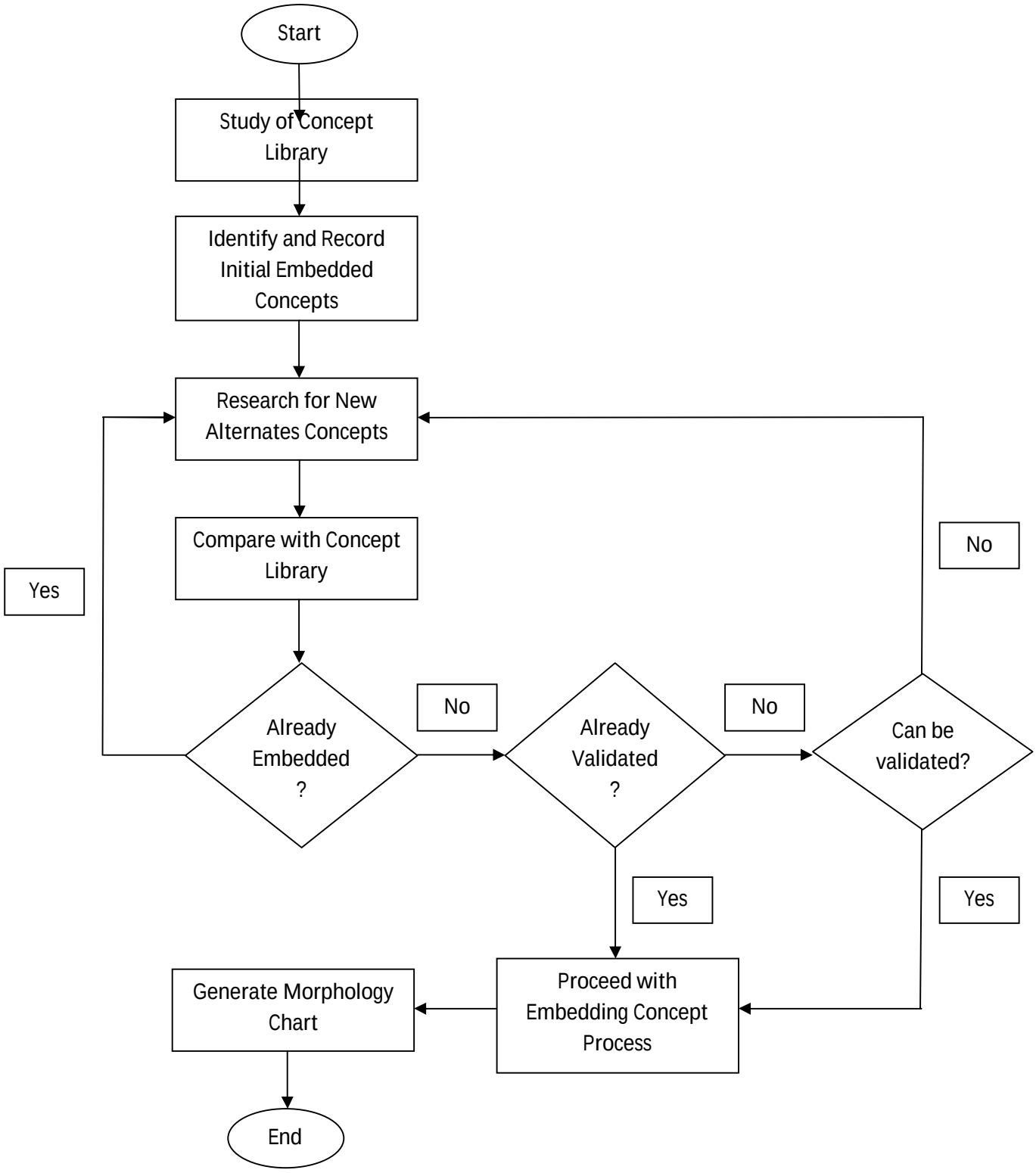


Figure 7: Development of Morphology Chart Process Flowchart

The flowchart in figure 7 explains the steps taken to ensure the process of developing the morphology chart running smoothly. The main steps for the development process are focused on selecting and identifying the new concepts to be embedded into the system. After a number of thought to be new concepts are selected, a list of new concepts, which are labelled as “New Concepts”, a process of comparison are done between the list of “New Concepts” and “Concepts Library List”. This is to identify that which of the concepts in the “New Concepts” list are deem to be already available in the “Concepts Library List” and will be discarded from moving on to the next step.

The new concepts that have been identified to be not in the concept library will need to be validated. This is to ensure that the concepts are proven to be effective and accepted by the industry. Thorough researches are done to make sure the concepts are validated and eligible to proceed to the next step of embedding the concepts into the concepts library. For the case of concepts that are not initially validated, a validation is required. If the concepts failed to be validate, it will be discarded and deem not effective and unaccepted by the industry.

After completing the embedding process, the final step is to generate the new enhance morphology chart for comparison with the old morphology chart. This is where the result will determine the success level of achieving the final objective of this project.

5.4 Validation of Concepts

For the purpose of achieving this project objective, all the concepts embedded inside the software need to be validated. This is to prove that the concepts are accepted and proven to be effective in the industry. To achieve proper validations, the new selected concepts are initially chosen from the concepts that are already available in the industry. The concepts are chosen from handbooks, patents, and research papers. This will help maintain the validity of the software.

In any case of concepts selected are not initially validated, in which the concepts are totally new and not yet proven in the industry, the concepts need to go through a validation process. For this purpose, the concept technical description and working principles need to be elaborate and presented to a person in charge and qualified to validate the concepts.

5.5 Capability Demonstration of CDST

For capability demonstration of the new version of upgraded CDST, a comparison will be done. This comparison is between the old versions of CDST with the newly upgraded CDST. A morphology chart with selected functions will be generated by both versions of CDST. The morphology charts are then compared with each other. The different amount of concepts displayed will be the main measuring criteria to determine the success of the new version of CDST.

Chapter 6
Result and Discussion

6.1 Introduction

This section will contain the results collected regarding this project. In this manner, a comparison between morphology charts generated by CSDTsped and CDST are done. The comparisons are conducted by generating morphology charts that the different is the content of the concept library. By comparing the number of concept variants identified from the morphology chart, the success of the objective of this project can be determined.

6.2 New Concepts

The concepts obtained will be categorized by their working functions in which they already been embedded according to. Each of the concepts illustration or schematic diagram is displayed accordingly (refer Appendix 12 & 13). All the concepts has been validated to and deem fit for application. A total of 24 concepts have been embedded into the design tool database.

6.3 Separate Gas from Liquid (Two-phase Flow Separator)

In this section, a preliminary Morphology chart form “Two Phase Flow Separator” is generated by using the design tool called “Conceptual Design Support Tool for Subsea Processing Equipment Design”, or known as CDSTsped. The functions selected for this purpose are as follows:

1. Distribute Liquid-Gas Mixture
2. Separate Liquid-Gas Mixture
3. Extract Liquid
4. Regulate Gas
5. Regulate Liquid

These functions represent the basic system for a two phase separator. The alternate concepts are displayed accordance to the order of the functions.

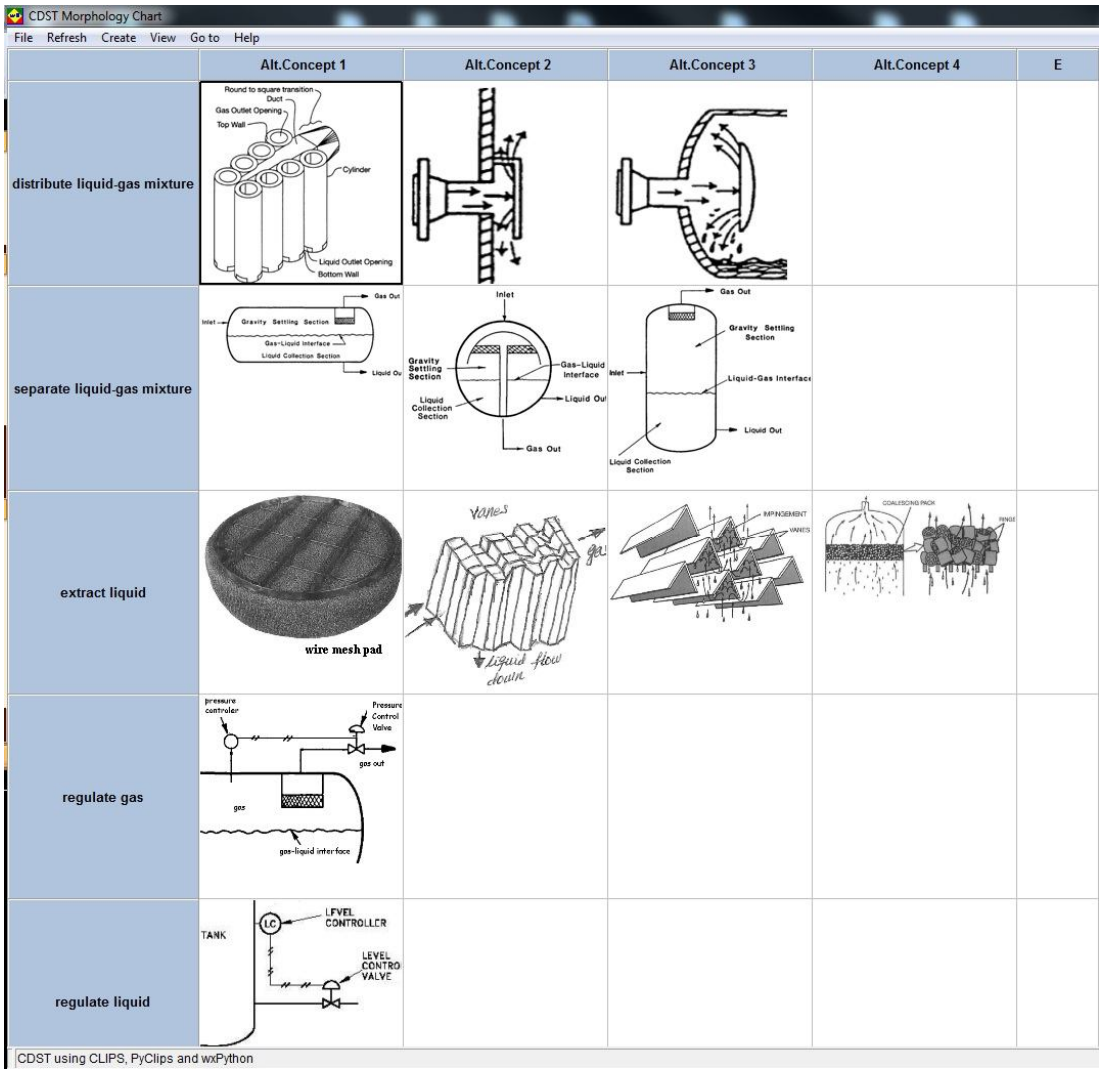


Figure 8: CDSTsped Morphology chart for Two-phase Separator

From Figure 8, the morphology chart generated by CDSTsped, a Concepts Variants list is generated automatically by the tool. This list represents the "theoretically possible combinations" of the functions selected in order to form a working system for a two phase separator. From the list (refer Appendix 1), the total number of possible combinations of concept variants is identified, which is amounting to a total of 36 Concept Variant.

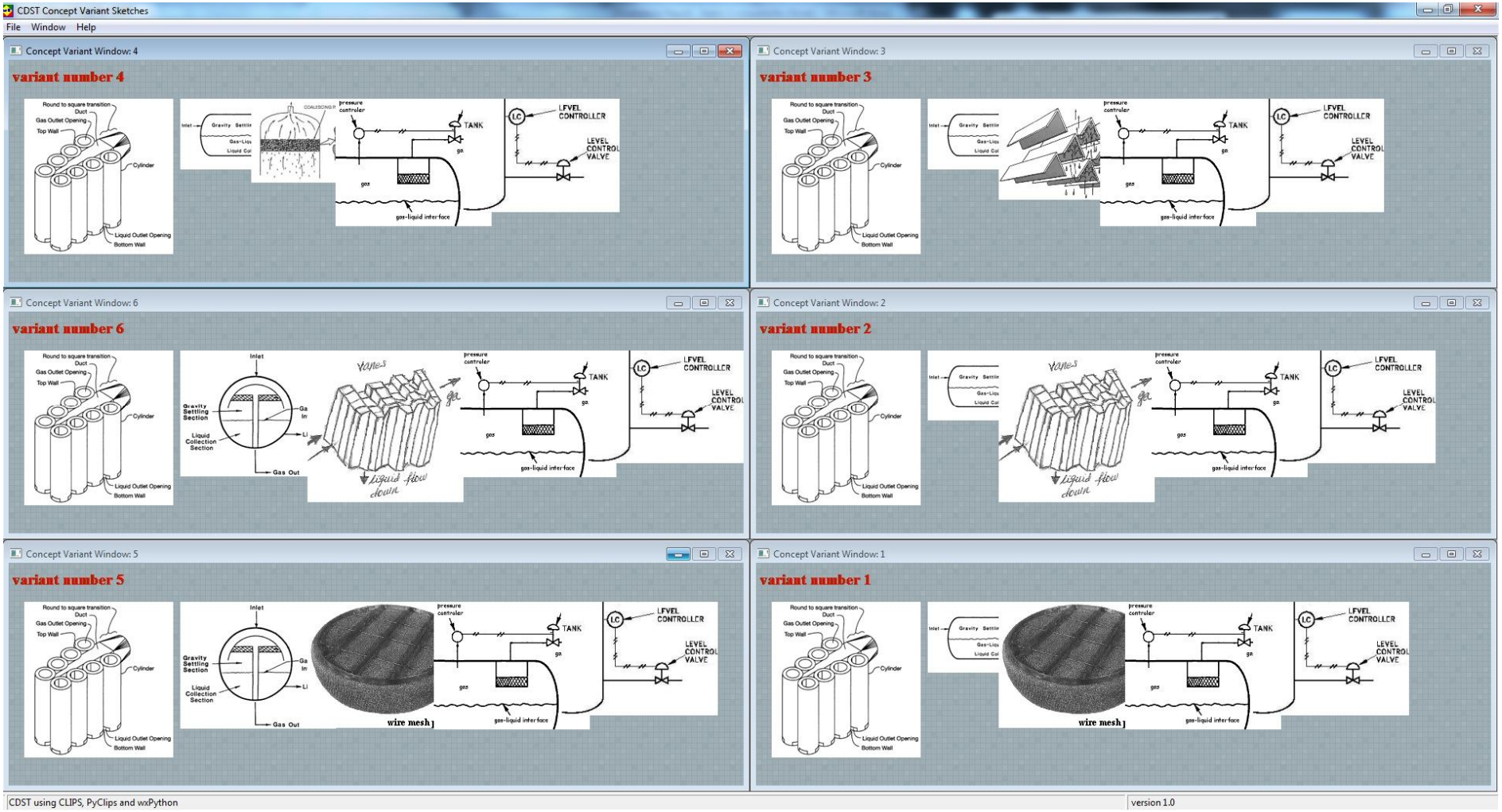


Figure 9: Concept Variants for CDSTsped Two-phase Separator

Similarly, by using the tool called “Conceptual Design Support Tool”, or known as CDST, a new morphology chart is generated by taking the same functions from CDSTsped as reference. This tool has been enhanced by adding new alternate concepts into the concepts library. Thus, by using the initial concepts (used by CDSTsped) and the new concepts, a morphology chart is generated. A Concepts Variants list is generated and the total number of possible combinations of concept variants identified is 2100 Concept Variant (refer Appendix 2).

Table 1: Total Number of Concept Variants Identified for Two-phase Separator

Concept Variants	Total
CDSTsped	36
CDST	2100

By comparing the two values of the total concept variants, the enhanced CDST generates more concept variants from the CDSTsped. This indicates that the enhanced CDST provide more options of solutions for the design problem of two phase separator.

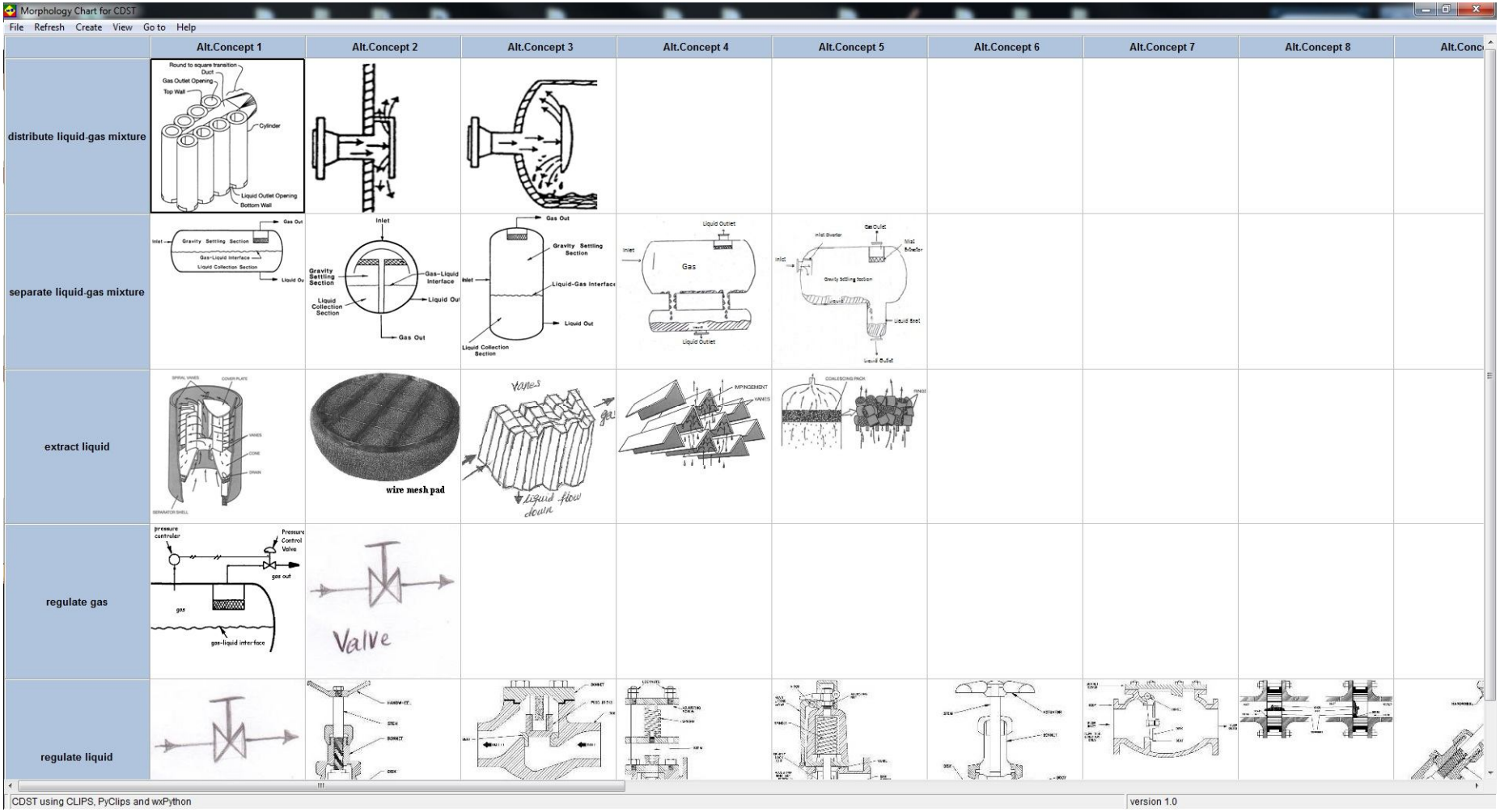


Figure 10: CDST Morphology Chart for Two-phase Separator

6.4 Separate Gas and Water from Oil (Three-phase Flow Separator)

By using the design tool CDSTsped, a preliminary morphology chart is generated. The functions selected for this product are as follows:

1. Distribute Liquid-Gas Mixture
2. Separate Liquid-Gas Mixture
3. Extract Liquid
4. Regulate Gas
5. Separate Liquid-Liquid Mixture
6. Regulate Liquid

These functions represent the basic system for a three phase separator. The alternate concepts are displayed accordance to the order of the functions listed.

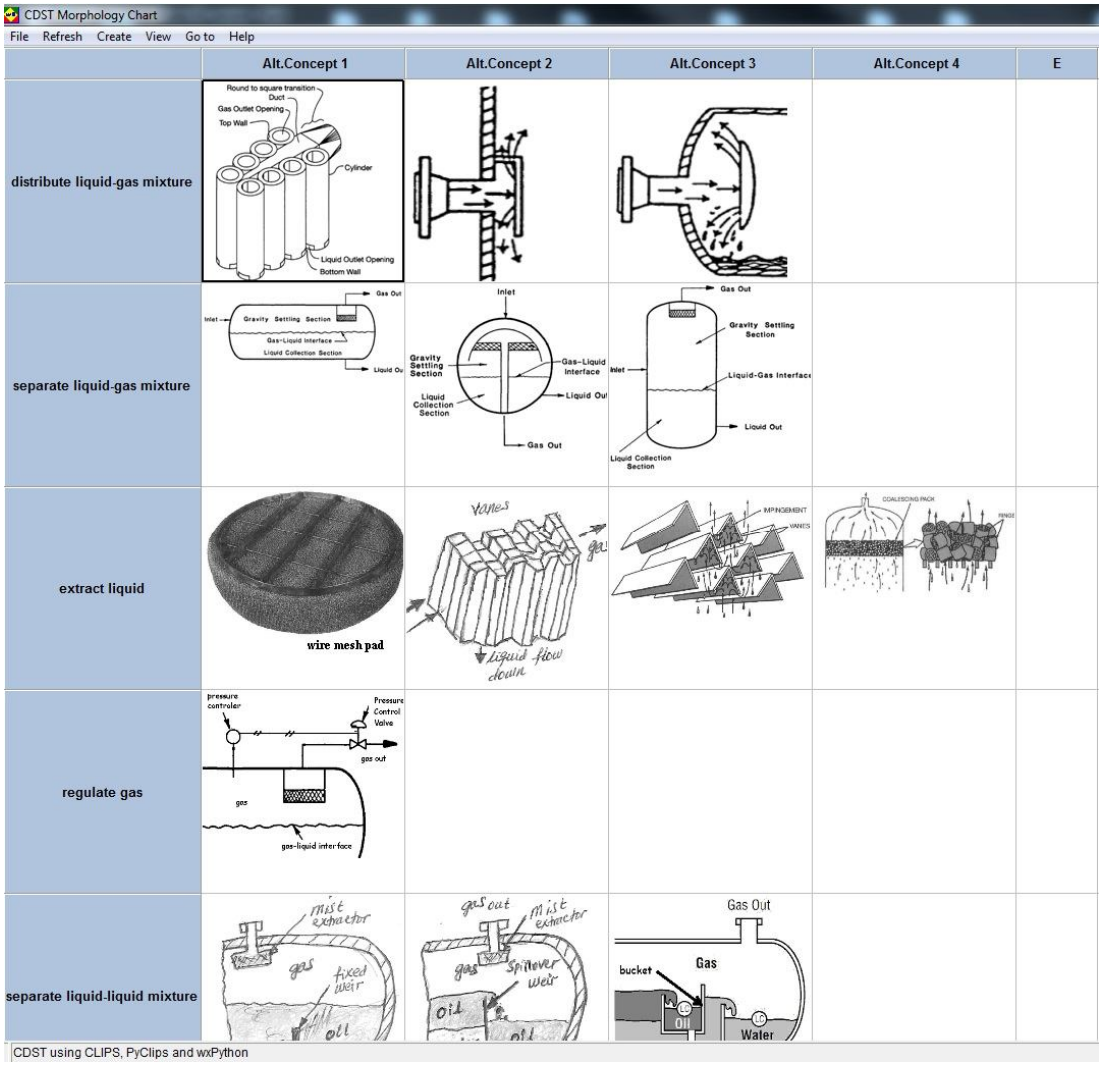


Figure 11: CDSTsped Morphology Chart for Three-phase Separator (1)

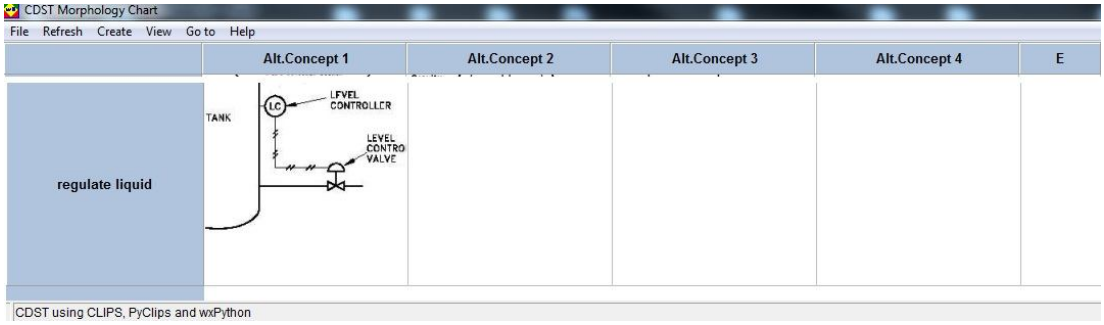


Figure 12: CDSTsped Morphology Chart for Three-phase Separator (2)

From Figure 11and Figure 12, the morphology chart generated by CDSTsped, a list of Concept Variants is generated (refer Appendix 3). The total number of possible combinations of concept variants identified is 108 Concept variant.

By using the enhanced design tool, CDST, a morphology chart is generated for the same product (refer Appendix 9 & 10). The list of Concepts Variants is generated with a total of 18900 Concept Variant of possible combinations are identified (refer Appendix 11). By comparing the two values of total concept variants, it's proven that the enhanced design tool, CDST, generated higher number of possible combinations

Table 2: Total Number of Concept Variants Identified for Three-phase Separator

Concept Variants	Total
CDSTsped	108
CDST	18900

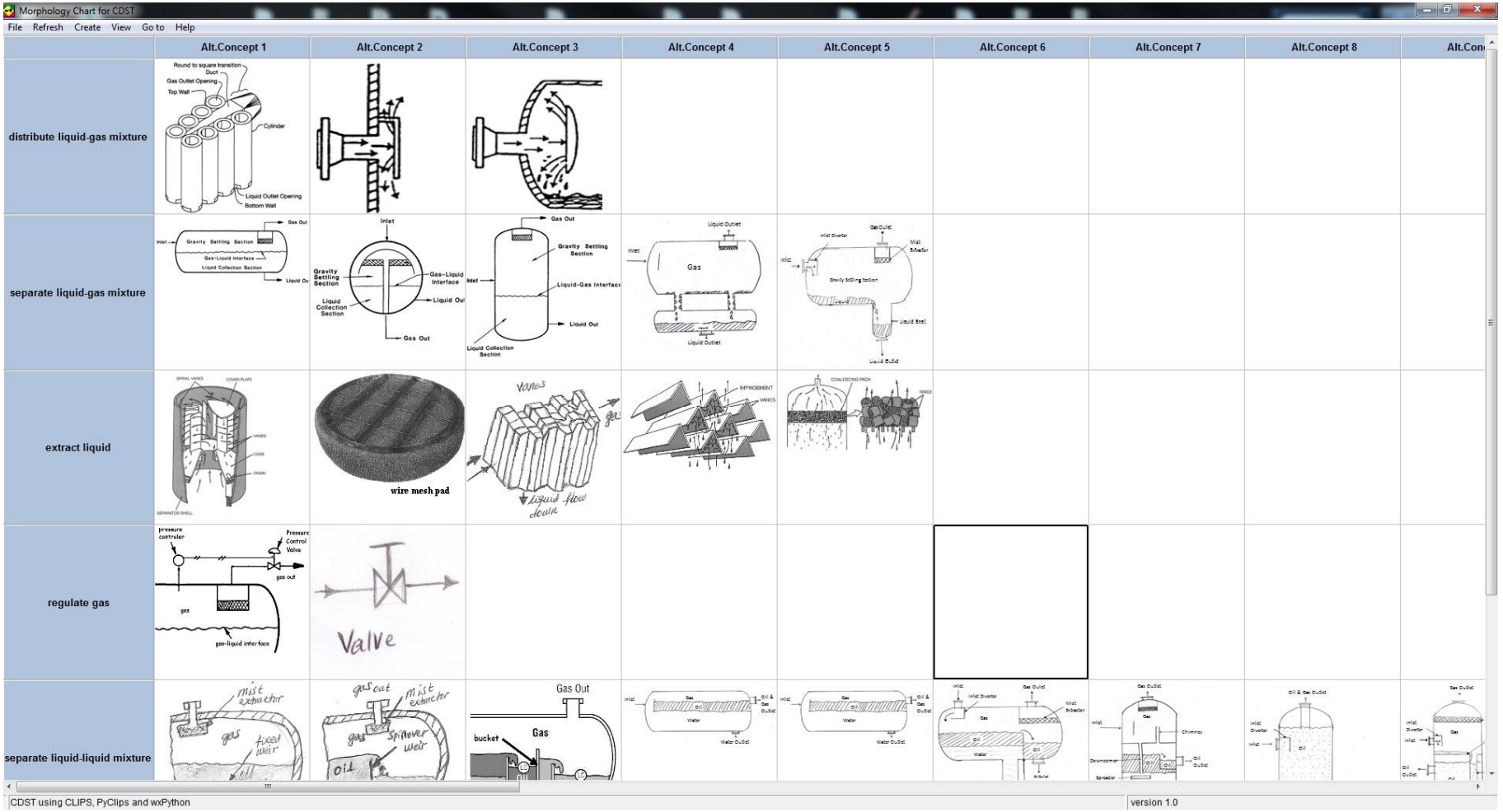


Figure 13: CDST Morphology Chart for Three-phase Separator (1)

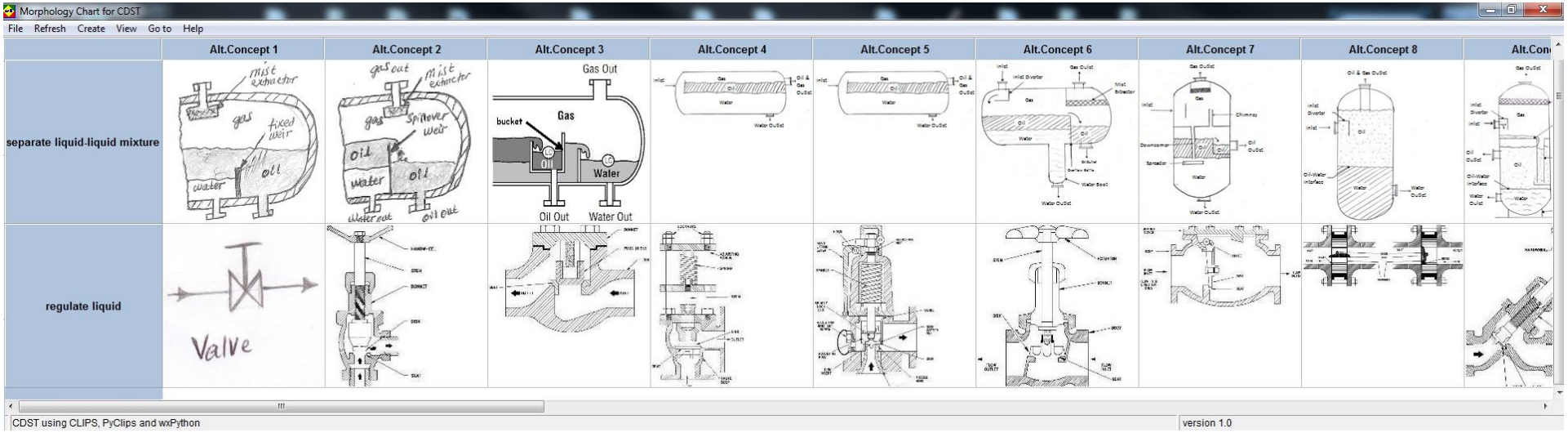


Figure 14: CDST Morphology Chart for Three-phase Separator (2)

Chapter 7
Conclusion

7.1 Conclusion

Based on this thesis, project objective are successfully achieve. All the new concepts that has been identified and validated have been embedded into the design tool, CDST database. With a total of 24 new design concepts has been embedded into the CDST database. The current version of the enhanced design tool CDST has more concepts compared to the previous version. This has been proven with the comparison of the morphology charts generated by both CDSTsped and CDST. By focusing on two classes of equipments, the Two-phase Separator and the Three-phase Separator, four morphology charts are generated, in which two are generated for each class. The results of comparison are determined by the concept variants that can be generated from the four different morphology charts.

Two-phase Separator has generated 36 concept variants by CDSTsped and 2100 concept variants by CDST. This shows an increment of 2064 concept variants. For Three-phase Separator, a total of 108 concepts variants are generated by CDSTsped and 18900 concepts variants generated by CDST. This also shows an increment in the concept variant total with 18792 concept variants. from the figure obtained, this has proven that the CDST has been successfully enhanced and have new added design concepts in the concept library.

7.1 Reccomendation

Throughout this project, the design tool CDST is successfully enhanced with respect to the subsea processing system. However, the design tool can still undergo further developments in the future. More new concepts for equipments can be added with respect to the oil and gas domain. Furthermore, for future development, the next author can focus on the programming aspect of the design tool.

References

[1] Fakhruldin, M. H., Woldemichael, D. E., (2011). *A framework for function-based conceptual design support system, Journal of Engineering, Design and Technology Vol. 9 No. 3, 2011.*

[2] Maultrie, J., . *Morphology Charts,* (retrieved from www.ifm.eng.cam.ac.uk/dmg/tools/concept/morph.html on 25/06/2012)

[3] *Fritz Zwicky*, (retrieved from http://en.wikipedia.org/wiki/Fritz_Zwicky on 25/06/2012)

[4] *Morphology Chart*, (retrieved from http://wikid.eu/index.php/Morphological_chart on 25/06/2012)

[5] *Subsea Technology*, (retrieved from http://en.wikipedia.org/wiki/Subsea on 25/06/2012)

[6] Hendriks, T., Fantoft, R., (2004) *Design and Performance – Testing of a New Solution for Subsea Separation*, Scandinavian Oil-Gas Magazine, Issued Aug 16, 2004. (retrieved from http://www.scandoil.com/moxie_issue-bm2/print_edtion/2004_/78-2004/design-and-performance-te.shtml)

[7] Prescott. C. N., (2012). *Subsea Separation and Processing of Oil, Gas & Produced Water, Past, Present and Future, Why We Need It Now,* (retrieved from http://www.forum.rice.edu/wpcontent/uploads/2011/06/011312RT_Prescott.pdf)

[8] Arnold. K., Stewart. M., (2008). *Surface Production Operations Design of Oil handling Systems and Facilities*, Third Edition, Volume One.

[9] Arnold. K., Stewart. M., (1989,1999). *Surface Production Operations Design of Oil handling Systems and Facilities*, Second Edition, Volume two.

[10] Arnold. K., Stewart. M., (2009). *Emulsions and Oil treating Equipment: Selection, Sizing and Troubleshooting*.

[11] Muir. J. A. R., (1998), *Downhole Production and Subsea Processing: Technical, business, and Environmental Solutions for the Industry.*

[12] Menon. E. S., Menon. P. S., (2010), *Working Guide to Pumps and Pumping Stations: Calculations and Simulation.*

[13] Leffler. L. W., Pattarozi. R., Sterling. G., (2003), *Deepwater Petroleum Exploration & Production: A Nontechnical Guide.*

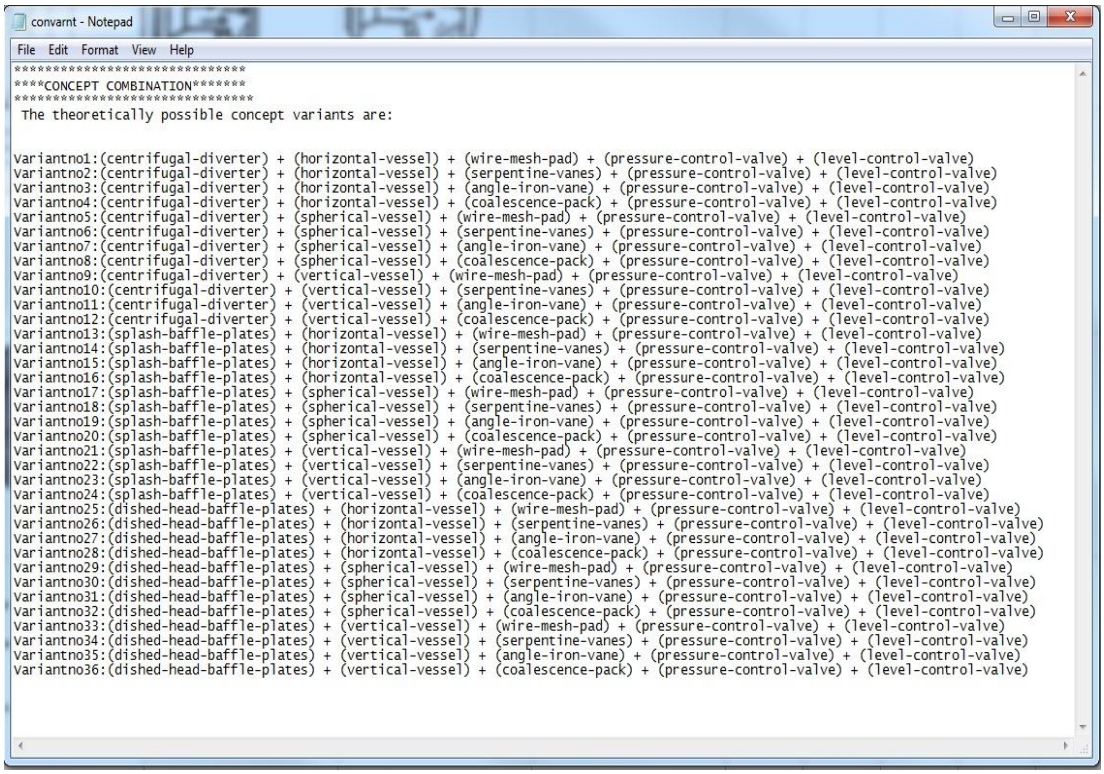
[14] http://www.pumps.org/content_detail_pumps.aspx?id=1772

[15] http://www.pumpschool.com/intro/index.asp

[16] http://nuclearpowertraining.tpub.com/h1018v2/index.htm

Appendix

Appendix 1: Concept variant List for CDSTsped Two-phase Separator



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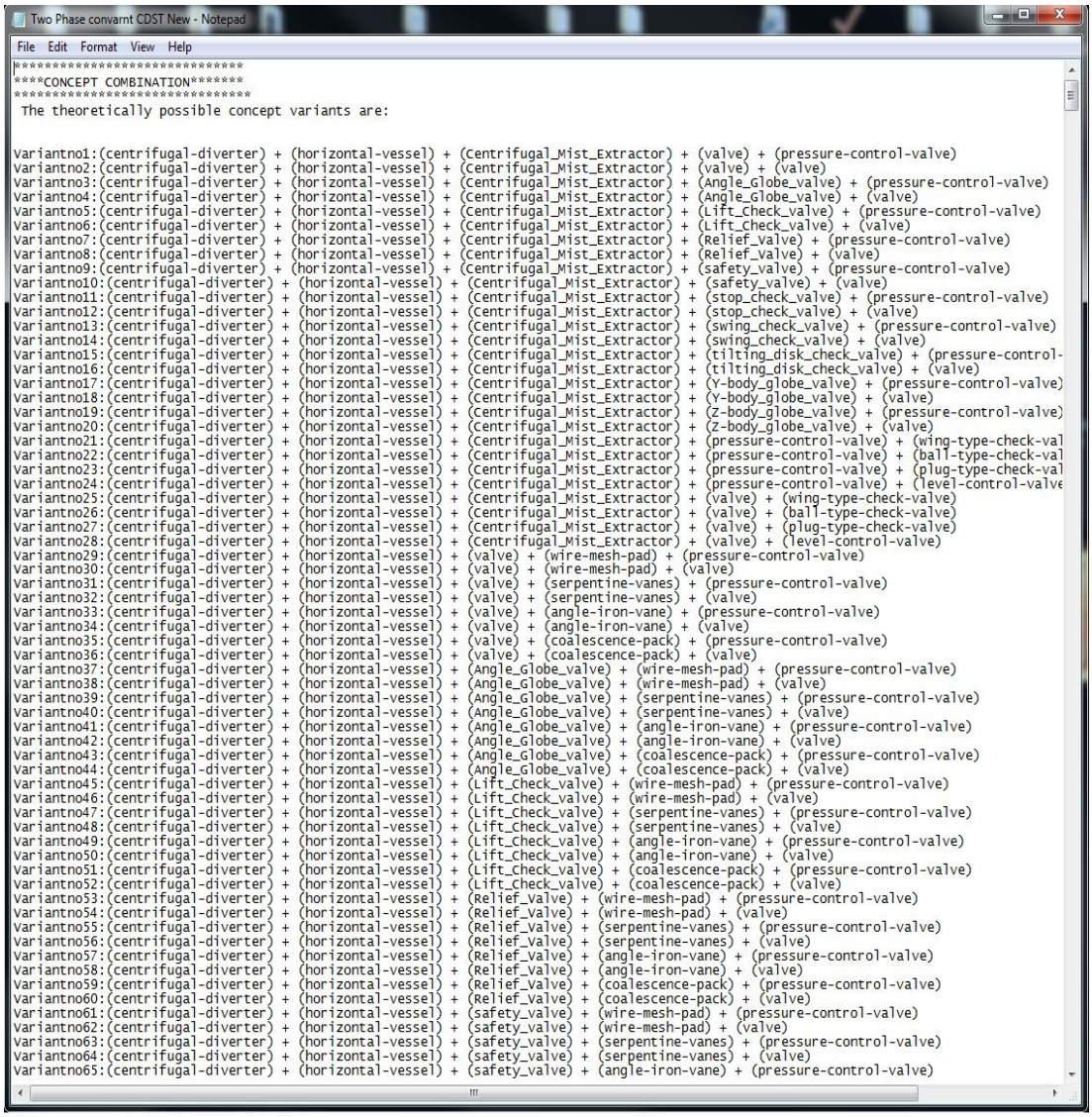
*********************************
****CONCEPT COMBINATION*******
*********************************
 The theoretically possible concept variants are:


Variantno1:(centrifugal-diverter) + (horizontal-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (level-control-valve)
Variantno2:(centrifugal-diverter) + (horizontal-vessel) + (serpentine-vanes) + (pressure-control-valve) + (level-control-valve)
Variantno3:(centrifugal-diverter) + (horizontal-vessel) + (angle-iron-vane) + (pressure-control-valve) + (level-control-valve)
Variantno4:(centrifugal-diverter) + (horizontal-vessel) + (coalescence-pack) + (pressure-control-valve) + (level-control-valve)
Variantno5:(centrifugal-diverter) + (spherical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (level-control-valve)
Variantno6:(centrifugal-diverter) + (spherical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (level-control-valve)
Variantno7:(centrifugal-diverter) + (spherical-vessel) + (angle-iron-vane) + (pressure-control-valve) + (level-control-valve)
Variantno8:(centrifugal-diverter) + (spherical-vessel) + (coalescence-pack) + (pressure-control-valve) + (level-control-valve)
Variantno9:(centrifugal-diverter) + (vertical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (level-control-valve)
Variantno10:(centrifugal-diverter) + (vertical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (level-control-valve)
Variantno11:(centrifugal-diverter) + (vertical-vessel) + (angle-iron-vane) + (pressure-control-valve) + (level-control-valve)
Variantno12:(centrifugal-diverter) + (vertical-vessel) + (coalescence-pack) + (pressure-control-valve) + (level-control-valve)
Variantno13:(splash-baffle-plates) + (horizontal-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (level-control-valve)
Variantno14:(splash-baffle-plates) + (horizontal-vessel) + (serpentine-vanes) + (pressure-control-valve) + (level-control-valve)
Variantno15:(splash-baffle-plates) + (horizontal-vessel) + (angle-iron-vane) + (pressure-control-valve) + (level-control-valve)
Variantno16:(splash-baffle-plates) + (horizontal-vessel) + (coalescence-pack) + (pressure-control-valve) + (level-control-valve)
Variantno17:(splash-baffle-plates) + (spherical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (level-control-valve)
Variantno18:(splash-baffle-plates) + (spherical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (level-control-valve)
Variantno19:(splash-baffle-plates) + (spherical-vessel) + (angle-iron-vane) + (pressure-control-valve) + (level-control-valve)
Variantno20:(splash-baffle-plates) + (spherical-vessel) + (coalescence-pack) + (pressure-control-valve) + (level-control-valve)
Variantno21:(splash-baffle-plates) + (vertical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (level-control-valve)
Variantno22:(splash-baffle-plates) + (vertical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (level-control-valve)
Variantno23:(splash-baffle-plates) + (vertical-vessel) + (angle-iron-vane) + (pressure-control-valve) + (level-control-valve)
Variantno24:(splash-baffle-plates) + (vertical-vessel) + (coalescence-pack) + (pressure-control-valve) + (level-control-valve)
Variantno25:(dished-head-baffle-plates) + (horizontal-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (level-control-valve)
Variantno26:(dished-head-baffle-plates) + (horizontal-vessel) + (serpentine-vanes) + (pressure-control-valve) + (level-control-valve)
Variantno27:(dished-head-baffle-plates) + (horizontal-vessel) + (angle-iron-vane) + (pressure-control-valve) + (level-control-valve)
Variantno28:(dished-head-baffle-plates) + (horizontal-vessel) + (coalescence-pack) + (pressure-control-valve) + (level-control-valve)
Variantno29:(dished-head-baffle-plates) + (spherical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (level-control-valve)
Variantno30:(dished-head-baffle-plates) + (spherical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (level-control-valve)
Variantno31:(dished-head-baffle-plates) + (spherical-vessel) + (angle-iron-vane) + (pressure-control-valve) + (level-control-valve)
Variantno32:(dished-head-baffle-plates) + (spherical-vessel) + (coalescence-pack) + (pressure-control-valve) + (level-control-valve)
Variantno33:(dished-head-baffle-plates) + (vertical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (level-control-valve)
Variantno34:(dished-head-baffle-plates) + (vertical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (level-control-valve)
Variantno35:(dished-head-baffle-plates) + (vertical-vessel) + (angle-iron-vane) + (pressure-control-valve) + (level-control-valve)
Variantno36:(dished-head-baffle-plates) + (vertical-vessel) + (coalescence-pack) + (pressure-control-valve) + (level-control-valve)
```

Appendix 2: Snapshot of Concept variant List for CDST Two-phase Separator



Two Phase convarnt CDST New - Notepad

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*********************************
****CONCEPT COMBINATION*******
*********************************
 The theoretically possible concept variants are:


Variantno1:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (valve) + (pressure-control-valve)
Variantno2:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (valve) + (valve)
Variantno3:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (Angle_Globe_valve) + (pressure-control-valve)
Variantno4:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (Angle_Globe_valve) + (valve)
Variantno5:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (Lift_Check_valve) + (pressure-control-valve)
Variantno6:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (Lift_Check_valve) + (valve)
Variantno7:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (Relief_Valve) + (pressure-control-valve)
Variantno8:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (Relief_Valve) + (valve)
Variantno9:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (safety_valve) + (pressure-control-valve)
Variantno10:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (safety_valve) + (valve)
Variantno11:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (stop_check_valve) + (pressure-control-valve)
Variantno12:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (stop_check_valve) + (valve)
Variantno13:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (swing_check_valve) + (pressure-control-valve)
Variantno14:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (swing_check_valve) + (valve)
Variantno15:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (tilting_disk_check_valve) + (pressure-control-
Variantno16:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (tilting_disk_check_valve) + (valve)
Variantno17:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (Y-body_globe_valve) + (pressure-control-valve)
Variantno18:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (Y-body_globe_valve) + (valve)
Variantno19:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (Z-body_globe_valve) + (pressure-control-valve)
Variantno20:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (Z-body_globe_valve) + (valve)
Variantno21:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (pressure-control-valve) + (wing-type-check-val
Variantno22:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (pressure-control-valve) + (ball-type-check-val
Variantno23:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (pressure-control-valve) + (plug-type-check-val
Variantno24:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (pressure-control-valve) + (level-control-valve
Variantno25:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (valve) + (wing-type-check-valve)
Variantno26:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (valve) + (ball-type-check-valve)
Variantno27:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (valve) + (plug-type-check-valve)
Variantno28:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (valve) + (level-control-valve)
Variantno29:(centrifugal-diverter) + (horizontal-vessel) + (valve) + (wire-mesh-pad) + (pressure-control-valve)
Variantno30:(centrifugal-diverter) + (horizontal-vessel) + (valve) + (wire-mesh-pad) + (valve)
Variantno31:(centrifugal-diverter) + (horizontal-vessel) + (valve) + (serpentine-vanes) + (pressure-control-valve)
Variantno32:(centrifugal-diverter) + (horizontal-vessel) + (valve) + (serpentine-vanes) + (valve)
Variantno33:(centrifugal-diverter) + (horizontal-vessel) + (valve) + (angle-iron-vane) + (pressure-control-valve)
Variantno34:(centrifugal-diverter) + (horizontal-vessel) + (valve) + (angle-iron-vane) + (valve)
Variantno35:(centrifugal-diverter) + (horizontal-vessel) + (valve) + (coalescence-pack) + (pressure-control-valve)
Variantno36:(centrifugal-diverter) + (horizontal-vessel) + (valve) + (coalescence-pack) + (valve)
Variantno37:(centrifugal-diverter) + (horizontal-vessel) + (Angle_Globe_valve) + (wire-mesh-pad) + (pressure-control-valve)
Variantno38:(centrifugal-diverter) + (horizontal-vessel) + (Angle_Globe_valve) + (wire-mesh-pad) + (valve)
Variantno39:(centrifugal-diverter) + (horizontal-vessel) + (Angle_Globe_valve) + (serpentine-vanes) + (pressure-control-valve)
Variantno40:(centrifugal-diverter) + (horizontal-vessel) + (Angle_Globe_valve) + (serpentine-vanes) + (valve)
Variantno41:(centrifugal-diverter) + (horizontal-vessel) + (Angle_Globe_valve) + (angle-iron-vane) + (pressure-control-valve)
Variantno42:(centrifugal-diverter) + (horizontal-vessel) + (Angle_Globe_valve) + (angle-iron-vane) + (valve)
Variantno43:(centrifugal-diverter) + (horizontal-vessel) + (Angle_Globe_valve) + (coalescence-pack) + (pressure-control-valve)
Variantno44:(centrifugal-diverter) + (horizontal-vessel) + (Angle_Globe_valve) + (coalescence-pack) + (valve)
Variantno45:(centrifugal-diverter) + (horizontal-vessel) + (Lift_Check_valve) + (wire-mesh-pad) + (pressure-control-valve)
Variantno46:(centrifugal-diverter) + (horizontal-vessel) + (Lift_Check_valve) + (wire-mesh-pad) + (valve)
Variantno47:(centrifugal-diverter) + (horizontal-vessel) + (Lift_Check_valve) + (serpentine-vanes) + (pressure-control-valve)
Variantno48:(centrifugal-diverter) + (horizontal-vessel) + (Lift_Check_valve) + (serpentine-vanes) + (valve)
Variantno49:(centrifugal-diverter) + (horizontal-vessel) + (Lift_Check_valve) + (angle-iron-vane) + (pressure-control-valve)
Variantno50:(centrifugal-diverter) + (horizontal-vessel) + (Lift_Check_valve) + (angle-iron-vane) + (valve)
Variantno51:(centrifugal-diverter) + (horizontal-vessel) + (Lift_Check_valve) + (coalescence-pack) + (pressure-control-valve)
Variantno52:(centrifugal-diverter) + (horizontal-vessel) + (Lift_Check_valve) + (coalescence-pack) + (valve)
Variantno53:(centrifugal-diverter) + (horizontal-vessel) + (Relief_Valve) + (wire-mesh-pad) + (pressure-control-valve)
Variantno54:(centrifugal-diverter) + (horizontal-vessel) + (Relief_Valve) + (wire-mesh-pad) + (valve)
Variantno55:(centrifugal-diverter) + (horizontal-vessel) + (Relief_Valve) + (serpentine-vanes) + (pressure-control-valve)
Variantno56:(centrifugal-diverter) + (horizontal-vessel) + (Relief_Valve) + (serpentine-vanes) + (valve)
Variantno57:(centrifugal-diverter) + (horizontal-vessel) + (Relief_Valve) + (angle-iron-vane) + (pressure-control-valve)
Variantno58:(centrifugal-diverter) + (horizontal-vessel) + (Relief_Valve) + (angle-iron-vane) + (valve)
Variantno59:(centrifugal-diverter) + (horizontal-vessel) + (Relief_Valve) + (coalescence-pack) + (pressure-control-valve)
Variantno60:(centrifugal-diverter) + (horizontal-vessel) + (Relief_Valve) + (coalescence-pack) + (valve)
Variantno61:(centrifugal-diverter) + (horizontal-vessel) + (safety_valve) + (wire-mesh-pad) + (pressure-control-valve)
Variantno62:(centrifugal-diverter) + (horizontal-vessel) + (safety_valve) + (wire-mesh-pad) + (valve)
Variantno63:(centrifugal-diverter) + (horizontal-vessel) + (safety_valve) + (serpentine-vanes) + (pressure-control-valve)
Variantno64:(centrifugal-diverter) + (horizontal-vessel) + (safety_valve) + (serpentine-vanes) + (valve)
Variantno65:(centrifugal-diverter) + (horizontal-vessel) + (safety_valve) + (angle-iron-vane) + (pressure-control-valve)
```
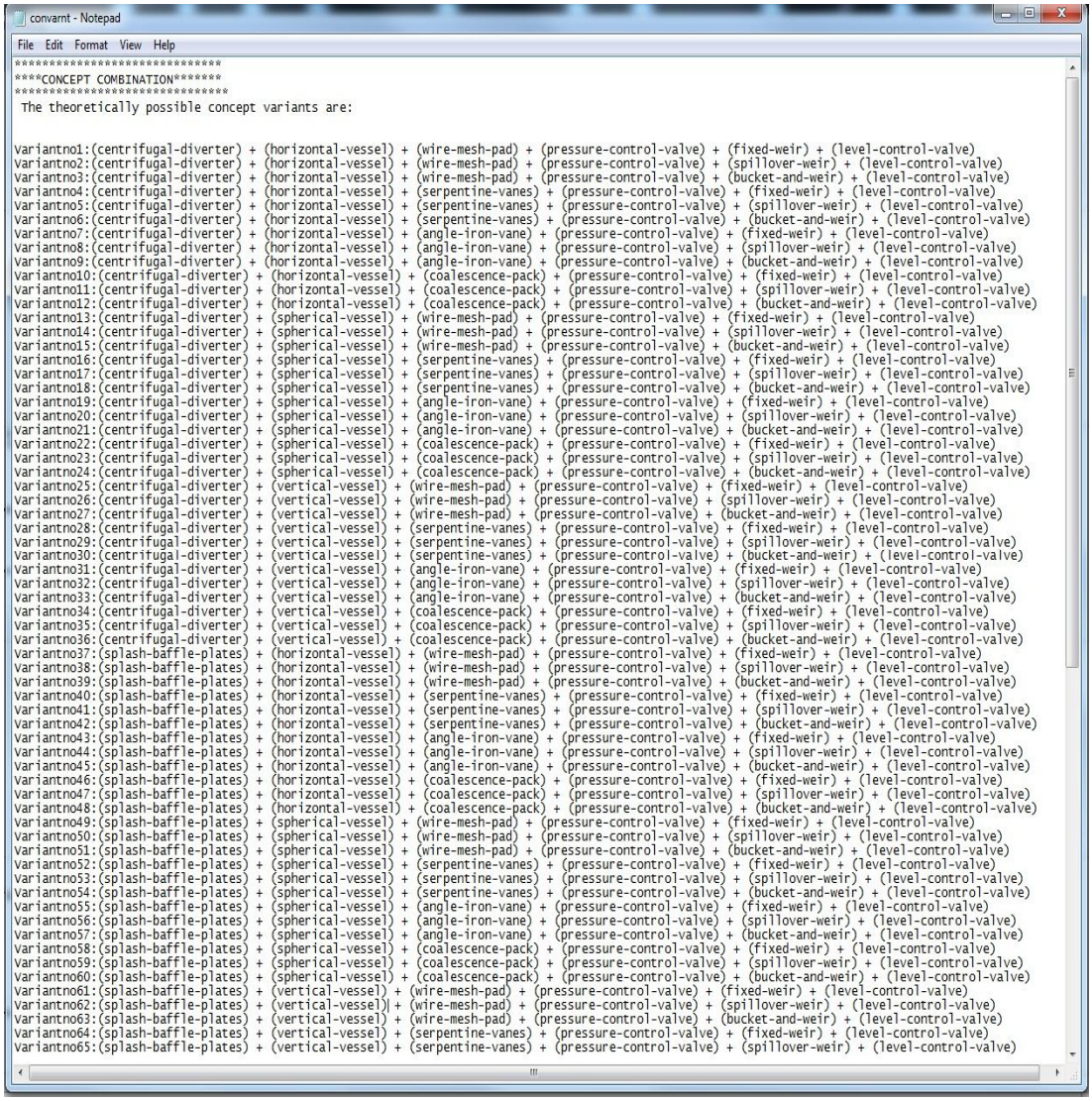

Appendix 3: Snapshot of Concept variant List for CDSTsped Three-phase Separator



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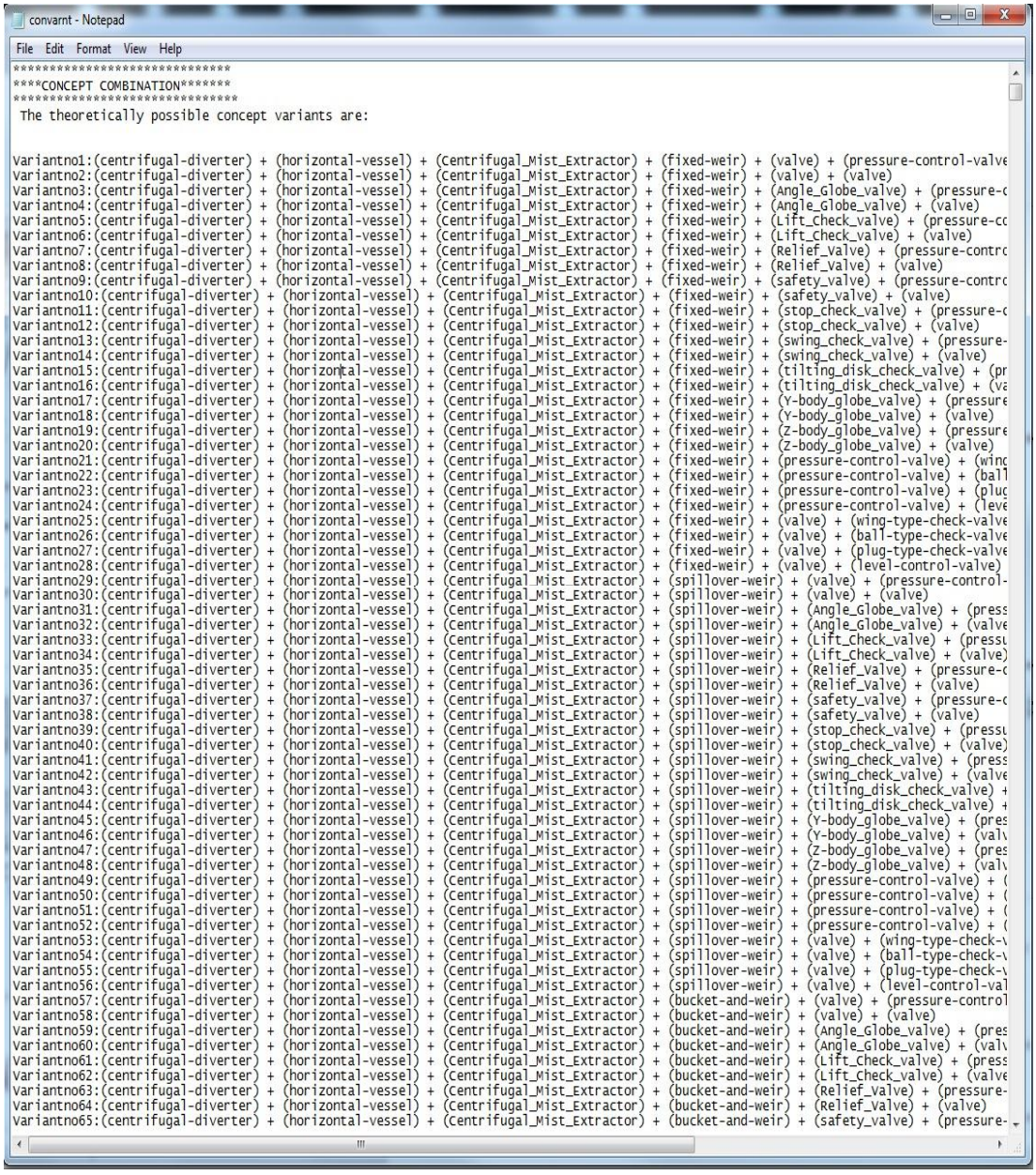
*******************************
****CONCEPT COMBINATION*******
*******************************
 The theoretically possible concept variants are:


variantno1:(centrifugal-diverter) + (horizontal-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno2:(centrifugal-diverter) + (horizontal-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno3:(centrifugal-diverter) + (horizontal-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno4:(centrifugal-diverter) + (horizontal-vessel) + (serpentine-vanes) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno5:(centrifugal-diverter) + (horizontal-vessel) + (serpentine-vanes) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno6:(centrifugal-diverter) + (horizontal-vessel) + (serpentine-vanes) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno7:(centrifugal-diverter) + (horizontal-vessel) + (angle-iron-vane) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno8:(centrifugal-diverter) + (horizontal-vessel) + (angle-iron-vane) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno9:(centrifugal-diverter) + (horizontal-vessel) + (angle-iron-vane) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno10:(centrifugal-diverter) + (horizontal-vessel) + (coalescence-pack) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno11:(centrifugal-diverter) + (horizontal-vessel) + (coalescence-pack) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno12:(centrifugal-diverter) + (horizontal-vessel) + (coalescence-pack) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno13:(centrifugal-diverter) + (spherical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno14:(centrifugal-diverter) + (spherical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno15:(centrifugal-diverter) + (spherical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno16:(centrifugal-diverter) + (spherical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno17:(centrifugal-diverter) + (spherical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno18:(centrifugal-diverter) + (spherical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno19:(centrifugal-diverter) + (spherical-vessel) + (angle-iron-vane) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno20:(centrifugal-diverter) + (spherical-vessel) + (angle-iron-vane) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno21:(centrifugal-diverter) + (spherical-vessel) + (angle-iron-vane) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno22:(centrifugal-diverter) + (spherical-vessel) + (coalescence-pack) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno23:(centrifugal-diverter) + (spherical-vessel) + (coalescence-pack) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno24:(centrifugal-diverter) + (spherical-vessel) + (coalescence-pack) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno25:(centrifugal-diverter) + (vertical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno26:(centrifugal-diverter) + (vertical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno27:(centrifugal-diverter) + (vertical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno28:(centrifugal-diverter) + (vertical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno29:(centrifugal-diverter) + (vertical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno30:(centrifugal-diverter) + (vertical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno31:(centrifugal-diverter) + (vertical-vessel) + (angle-iron-vane) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno32:(centrifugal-diverter) + (vertical-vessel) + (angle-iron-vane) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno33:(centrifugal-diverter) + (vertical-vessel) + (angle-iron-vane) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno34:(centrifugal-diverter) + (vertical-vessel) + (coalescence-pack) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno35:(centrifugal-diverter) + (vertical-vessel) + (coalescence-pack) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno36:(centrifugal-diverter) + (vertical-vessel) + (coalescence-pack) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno37:(splash-baffle-plates) + (horizontal-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno38:(splash-baffle-plates) + (horizontal-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno39:(splash-baffle-plates) + (horizontal-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno40:(splash-baffle-plates) + (horizontal-vessel) + (serpentine-vanes) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno41:(splash-baffle-plates) + (horizontal-vessel) + (serpentine-vanes) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno42:(splash-baffle-plates) + (horizontal-vessel) + (serpentine-vanes) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno43:(splash-baffle-plates) + (horizontal-vessel) + (angle-iron-vane) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno44:(splash-baffle-plates) + (horizontal-vessel) + (angle-iron-vane) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno45:(splash-baffle-plates) + (horizontal-vessel) + (angle-iron-vane) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno46:(splash-baffle-plates) + (horizontal-vessel) + (coalescence-pack) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno47:(splash-baffle-plates) + (horizontal-vessel) + (coalescence-pack) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno48:(splash-baffle-plates) + (horizontal-vessel) + (coalescence-pack) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno49:(splash-baffle-plates) + (spherical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno50:(splash-baffle-plates) + (spherical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno51:(splash-baffle-plates) + (spherical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno52:(splash-baffle-plates) + (spherical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno53:(splash-baffle-plates) + (spherical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno54:(splash-baffle-plates) + (spherical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno55:(splash-baffle-plates) + (spherical-vessel) + (angle-iron-vane) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno56:(splash-baffle-plates) + (spherical-vessel) + (angle-iron-vane) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno57:(splash-baffle-plates) + (spherical-vessel) + (angle-iron-vane) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno58:(splash-baffle-plates) + (spherical-vessel) + (coalescence-pack) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno59:(splash-baffle-plates) + (spherical-vessel) + (coalescence-pack) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno60:(splash-baffle-plates) + (spherical-vessel) + (coalescence-pack) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno61:(splash-baffle-plates) + (vertical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno62:(splash-baffle-plates) + (vertical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
variantno63:(splash-baffle-plates) + (vertical-vessel) + (wire-mesh-pad) + (pressure-control-valve) + (bucket-and-weir) + (level-control-valve)
variantno64:(splash-baffle-plates) + (vertical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (fixed-weir) + (level-control-valve)
variantno65:(splash-baffle-plates) + (vertical-vessel) + (serpentine-vanes) + (pressure-control-valve) + (spillover-weir) + (level-control-valve)
```

Appendix 4: Snapshot of Concept variant List for CDST Three-phase Separator



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**********
****CONCEPT COMBINATION*******
**********
 The theoretically possible concept variants are:


Variantno1:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (valve) + (pressure-control-valve
Variantno2:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (valve) + (valve)
Variantno3:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (Angle_Globe_valve) + (pressure-c
Variantno4:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (Angle_Globe_valve) + (valve)
Variantno5:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (Lift_Check_valve) + (pressure-cc
Variantno6:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (Lift_Check_valve) + (valve)
Variantno7:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (Relief_Valve) + (pressure-contro
Variantno8:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (Relief_Valve) + (valve)
Variantno9:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (safety_valve) + (pressure-contro
Variantno10:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (safety_valve) + (valve)
Variantno11:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (stop_check_valve) + (pressure-c
Variantno12:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (stop_check_valve) + (valve)
Variantno13:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (swing_check_valve) + (pressure-
Variantno14:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (swing_check_valve) + (valve)
Variantno15:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (tilting_disk_check_valve) + (pr
Variantno16:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (tilting_disk_check_valve) + (va
Variantno17:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (Y-body_globe_valve) + (pressure
Variantno18:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (Y-body_globe_valve) + (valve)
Variantno19:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (Z-body_globe_valve) + (pressure
Variantno20:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (Z-body_globe_valve) + (valve)
Variantno21:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (pressure-control-valve) + (winc
Variantno22:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (pressure-control-valve) + (ball
Variantno23:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (pressure-control-valve) + (plug
Variantno24:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (pressure-control-valve) + (leve
Variantno25:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (valve) + (wing-type-check-valve
Variantno26:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (valve) + (ball-type-check-valve
Variantno27:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (valve) + (plug-type-check-valve
Variantno28:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (fixed-weir) + (valve) + (level-control-valve)
Variantno29:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (valve) + (pressure-control-
Variantno30:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (valve) + (valve)
Variantno31:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (Angle_Globe_valve) + (press
Variantno32:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (Angle_Globe_valve) + (valve
Variantno33:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (Lift_Check_valve) + (pressu
Variantno34:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (Lift_Check_valve) + (valve)
Variantno35:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (Relief_Valve) + (pressure-c
Variantno36:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (Relief_Valve) + (valve)
Variantno37:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (safety_valve) + (pressure-c
Variantno38:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (safety_valve) + (valve)
Variantno39:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (stop_check_valve) + (pressu
Variantno40:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (stop_check_valve) + (valve)
Variantno41:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (swing_check_valve) + (press
Variantno42:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (swing_check_valve) + (valve
Variantno43:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (tilting_disk_check_valve) +
Variantno44:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (tilting_disk_check_valve) +
Variantno45:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (Y-body_globe_valve) + (pres
Variantno46:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (Y-body_globe_valve) + (valv
Variantno47:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (Z-body_globe_valve) + (pres
Variantno48:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (Z-body_globe_valve) + (valv
Variantno49:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (pressure-control-valve) + (
Variantno50:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (pressure-control-valve) + (
Variantno51:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (pressure-control-valve) + (
Variantno52:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (pressure-control-valve) + (
Variantno53:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (valve) + (wing-type-check-v
Variantno54:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (valve) + (ball-type-check-v
Variantno55:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (valve) + (plug-type-check-v
Variantno56:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (spillover-weir) + (valve) + (level-control-val
Variantno57:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (bucket-and-weir) + (valve) + (pressure-control
Variantno58:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (bucket-and-weir) + (valve) + (valve)
Variantno59:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (bucket-and-weir) + (Angle_Globe_valve) + (pres
Variantno60:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (bucket-and-weir) + (Angle_Globe_valve) + (valv
Variantno61:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (bucket-and-weir) + (Lift_Check_valve) + (press
Variantno62:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (bucket-and-weir) + (Lift_Check_valve) + (valve
Variantno63:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (bucket-and-weir) + (Relief_Valve) + (pressure-
Variantno64:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (bucket-and-weir) + (Relief_Valve) + (valve)
Variantno65:(centrifugal-diverter) + (horizontal-vessel) + (Centrifugal_Mist_Extractor) + (bucket-and-weir) + (safety_valve) + (pressure-
```
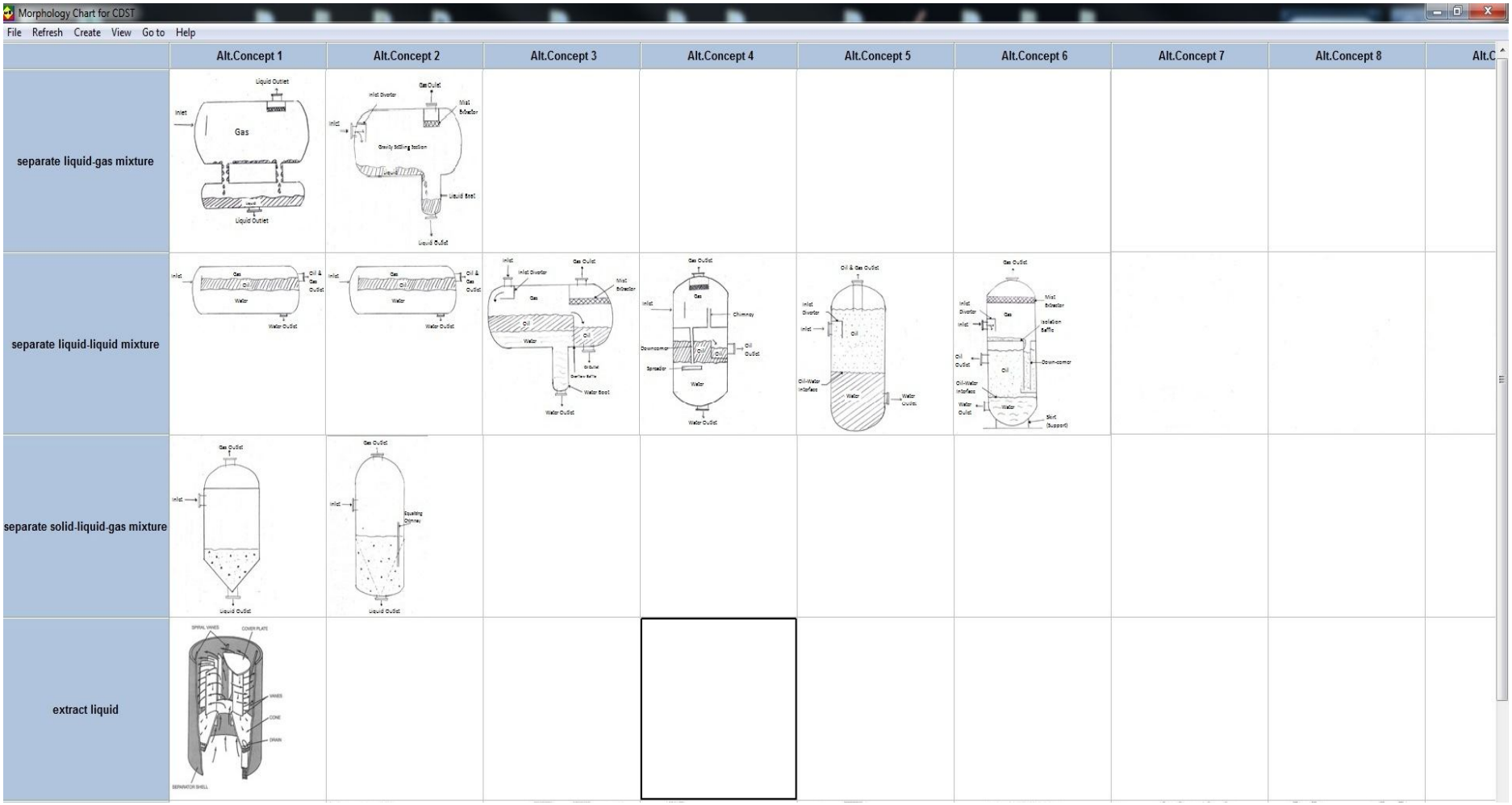
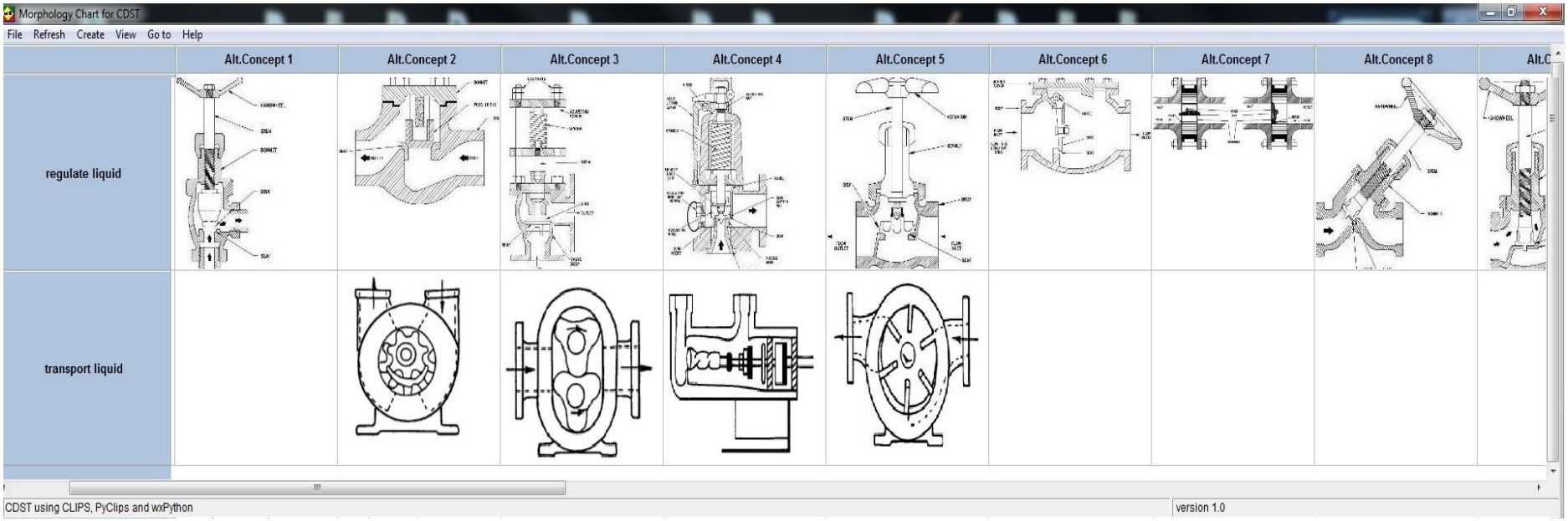

Appendix 5: Snapshot of New Concepts Embedded into CDST Database (1)



Appendix 6: Snapshot of New Concepts Embedded into CDST Database (2)



Appendix 7: Research Work Schedule (Gantt Chart)

Activity	Final Year 1st Semester													Final Year 2nd Semester												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1. Selection of title and background study of project																												
2. Preliminary Research work • Familiarization of software • Thorough research work on Subsea Processing System																												
3. Development of Software • Indentifying new concepts • Embedding new concepts																												
4. CDST Demonstration • Model simulation • Morphology Chart Comparison																												
5. Submission of Final Report • Report writing • Final presentation																												

Milestone

Title Selected and Background Study Conducted

Software Enhancement

Final Report and Presentatio

Familiarization and Research Work Completed

Morphology Chart Comparison