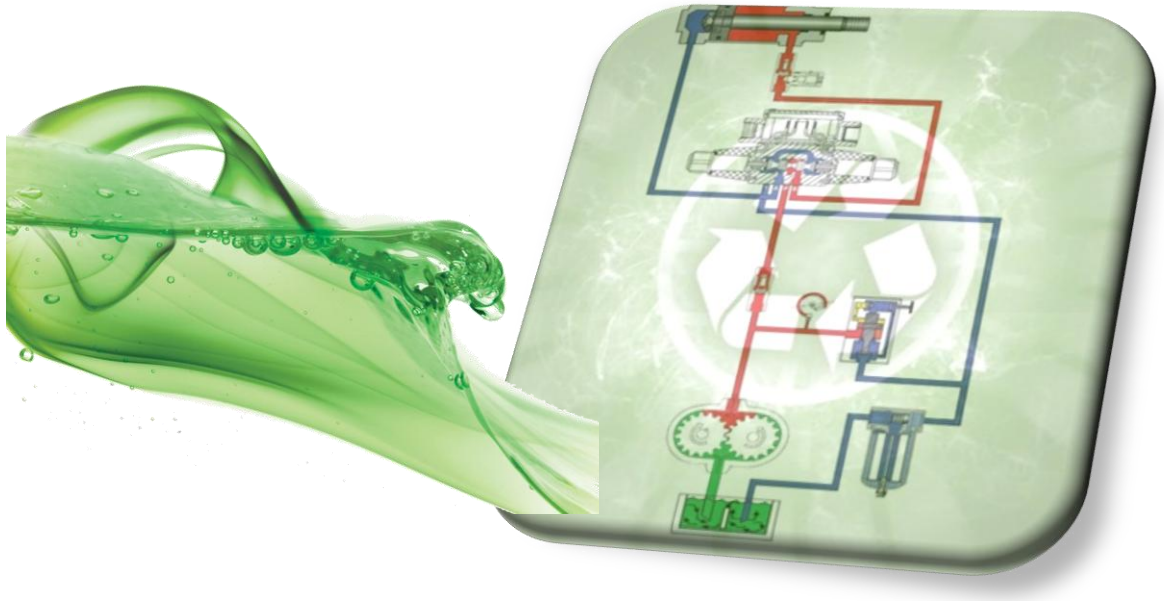
WIEFP 2014

SYSTEMATIZATION OF HYDRAULIC SYSTEMS DESIGN FOR USE WITH BIODEGRADABLE FLUIDS



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LASHIP – Laboratory of Hydraulic and Pneumatic Systems

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Summary

1. Introduction
2. Biodegradable Fluids
3. Systematization of Hydraulic System Design with Biodegradable Fluids – SHBIO
4. Expert System Prototype
5. Conclusions

1. Introduction

1.1 Contextualization

European studies have identified the leak of hydraulic fluid as a major source of groundwater contamination (EICHENBERGER, 1991).

A very conservative estimate is that more than 600 to 900 million gallons of fluid from hydraulic systems enter the environment every year (HAMID, 2008).

- HPP Sayano accident: Oil spill of 30,000 litres into The Yenisei river (2009).

- The São Martinho sugar mill in 2003, 108,622 litres of hydraulic oil were wasted from harvesters, as a result of failures of hydraulic systems (Tomazela (2007).

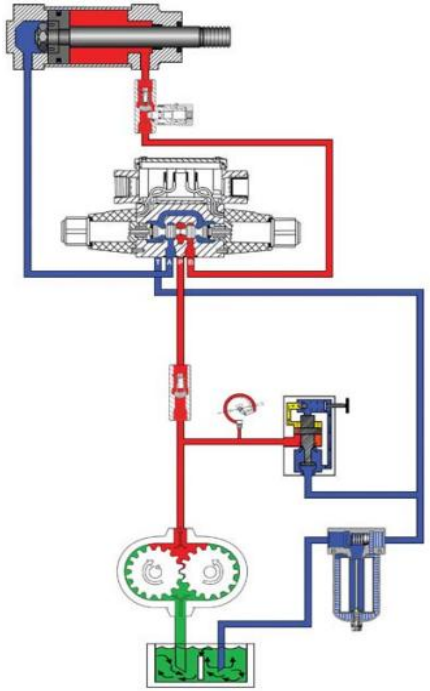
1.1 Contextualization

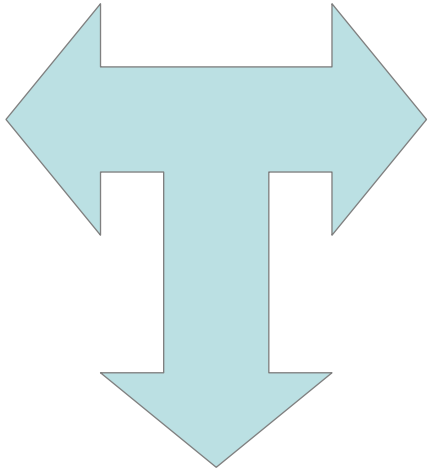
- In order to avoid or mitigate the issue of environmental risk, is identified in Brazil and the world, a way of incentives in search of systems development and/or environmentally friendly products.

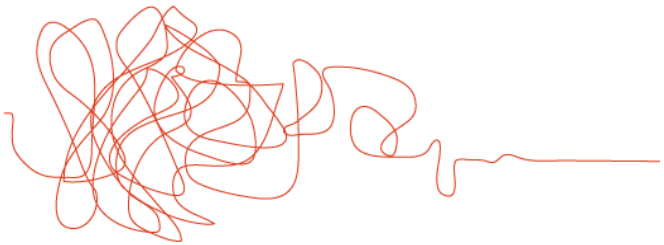
- Some of these industrial applications and research activities have broken the paradigm to use mineral oil for hydraulic systems, providing solutions with biodegradable hydraulic fluids.

1.2 Problem

The focus of the problem identified for this work is the deficiency of design processes for hydraulic systems that fit for use with biodegradable fluids.







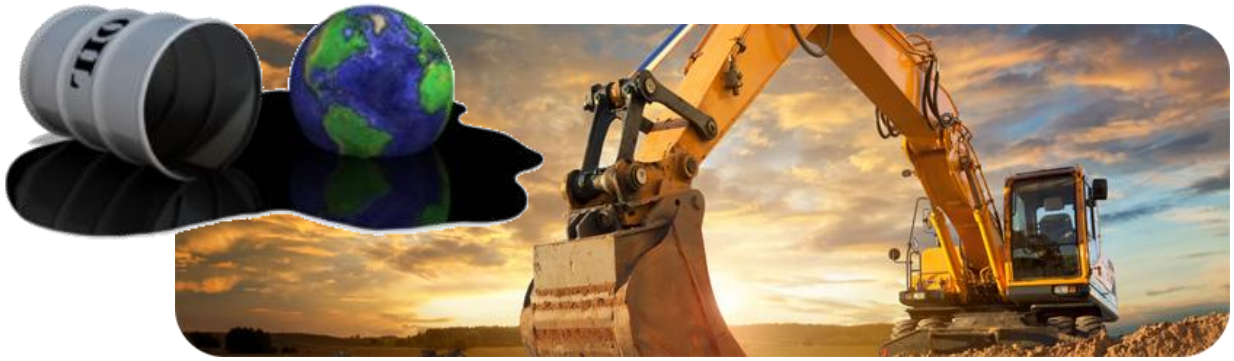
the design process

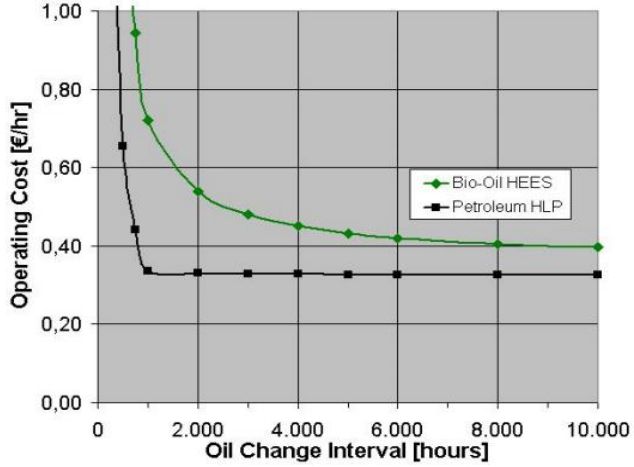
1.3 Justification

- In the context of development of Brazil, it is important to encourage the use and development of biodegradable fluids.
- There are not works found in the industrial and research scope that combine the design of hydraulic system together with biodegradable fluids.

- The value added to the use of biodegradable fluids is related to:

- The fluid life
- Reducing taxes for environmentally friendly policies, obtaining carbon credits
- Prevent fines due to accidents related to oil spills in water or soil.





THEISSEN, 2007

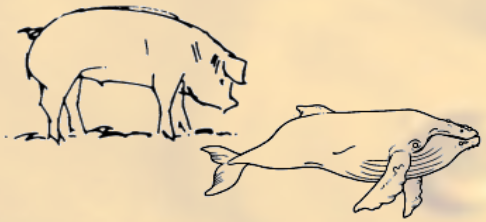
2. Biodegradable fluids

2.1 Timeline

- **Before 19th century, lubricating oils were natural, based mainly on rapeseed, soybean and castor oils or based on animal fat such as whale oil. (WILSON, 1998)**

- **Incentive of the EU for the use of biodegradable fluids.**
- **Requirement of the German government in specific applications.**

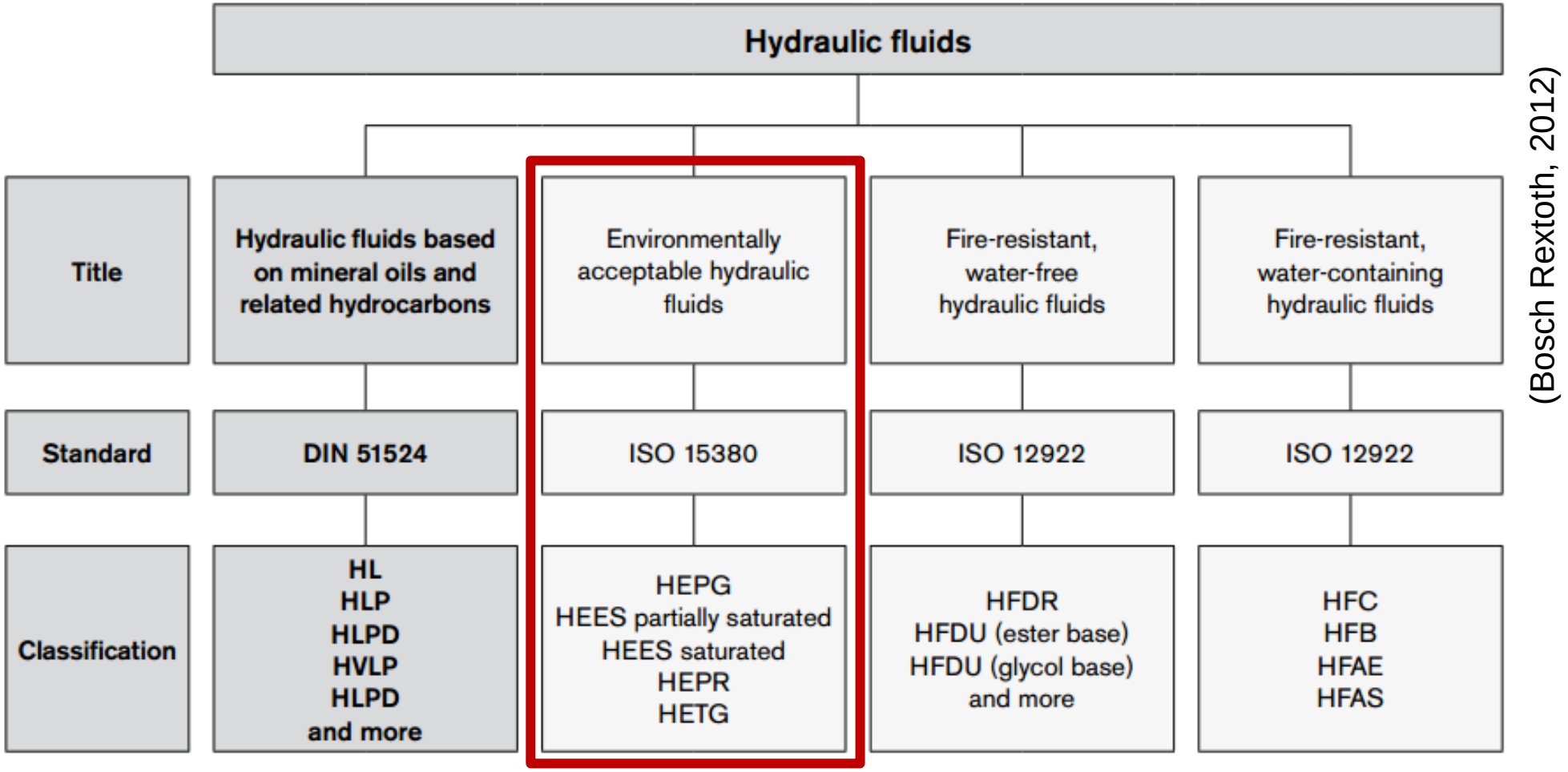
1800 1900 2000 2013



- **Rudolf Diesel is credited as the inventor of the first diesel engine which was originally designed to run on fuel derived from peanut oil.**

- **Different applications with biodegradable fluids in hydraulic systems**
- **Eco-labels**

2.2 Classification



(Bosch Rextoth, 2012)

- HEPG - Hydraulic Oil Environmental PolyGlycol.
- HEES - Hydraulic Oil Environmental Ester Synthetic.
- HEPR - Hydraulic Oil Environmental Polyalphaolefine and Related Products
- HETG - Hydraulic Oil Environmental TriGlyceride.

- High biodegradability
- Low toxicity
- High viscosity index
- High lubricity
- High flash point

- Thermal problems
- Low hydrolytic stability
- Low oxidation stability
- Cost

Ester, Polyglycol,
Triglyceride (vegetable),
Polyolefin

3. Systematization of Hydraulic System Design with Biodegradable Fluids - SHBIO

- The inclusion of a new variable (biodegradable fluids) show the need for new methods of design support.

- New or modified requirements require the support of various fields of knowledge.

- This new systematization must allow the effective integration of project teams, establish common information and provide assurance to the designer in making decisions.

SHBIO

- Systematization of procedures
- Specifying and analyzing requirements of hydraulic systems
- Adapt and optimize the performance and component life, as well as the fluid itself.

Selection of fluids ➔ Selection of components ➔ Guidelines for monitoring

3.1 SHBIO - Proposal

SHBIO – SYSTEMATIZATION OF HYDRAULIC SYSTEM DESIGN WITH BIODEGRADABLE FLUIDS

1st Phase: Biodegradable fluid selection

- Fluid properties
- Types of fluid
- International eco-labels
- Manufacturer's data sheet

2nd Phase: Selection of hydraulic components

- Reservoir
- Hydraulic pumps
- Actuation system
- Acumulator
- Filters

3th Phase: Monitoring of hydraulic system

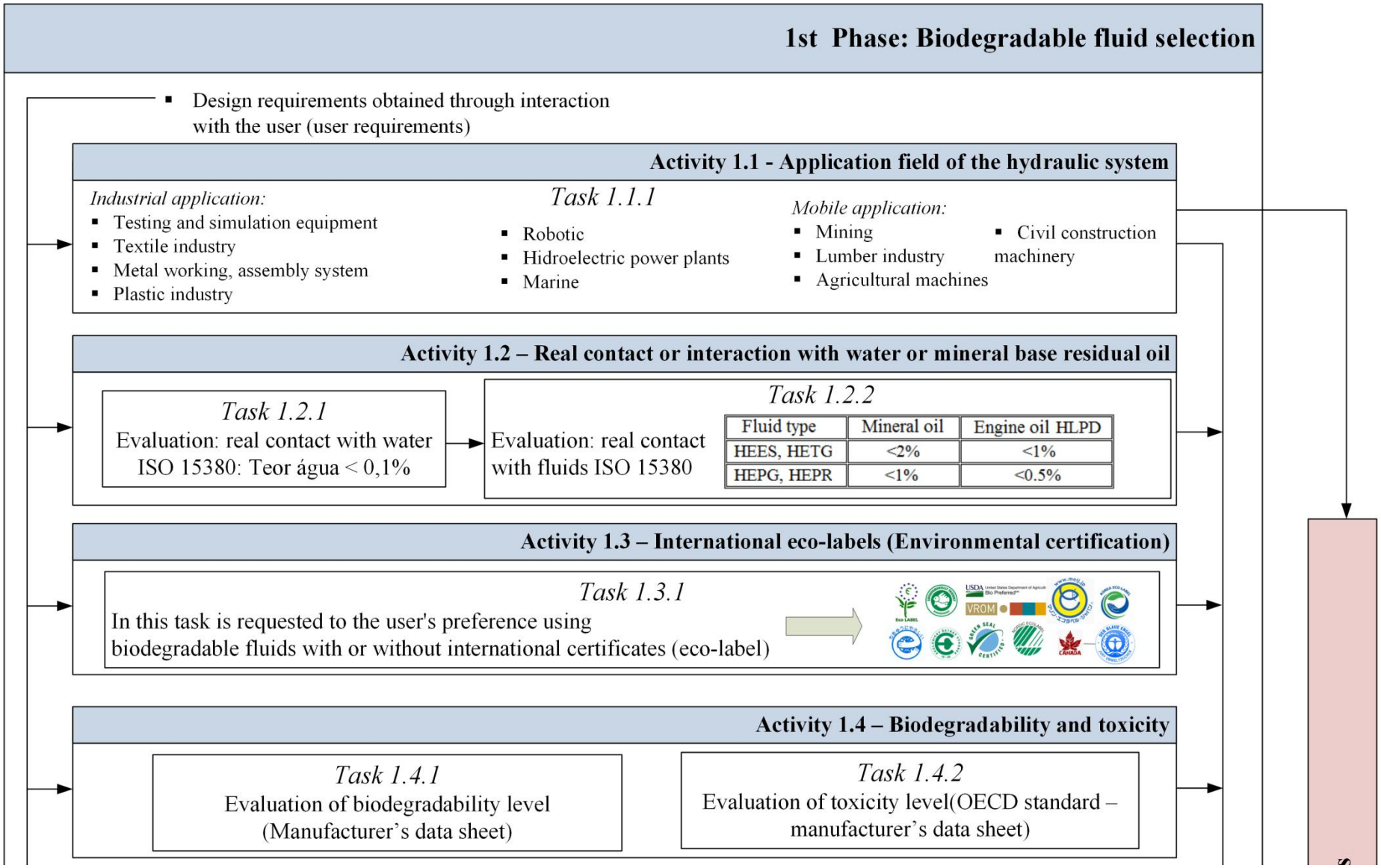
- Sensors
  - Temperature
  - Viscosity
  - humidity
  - Dielectric constant
  - Counter particles
- Monitoring points

4th phase: Solutions

- Final report

- Biodegradable fluids recommended
- Selection (specification) of components
- Guidelines of monitoring

3.2 1st phase - Biodegradable fluid selection



Activity 1.1 Application field of the hydraulic system:

A series of applications where biodegradable hydraulic fluid can be used are listed.

Industrial application:

- Testing and simulation equipment
- Textile industry,
- Plastic industry
- Metal working
- Assembly system,
- Robotic
- Hydroelectric power plants
- Marine

Mobile application:

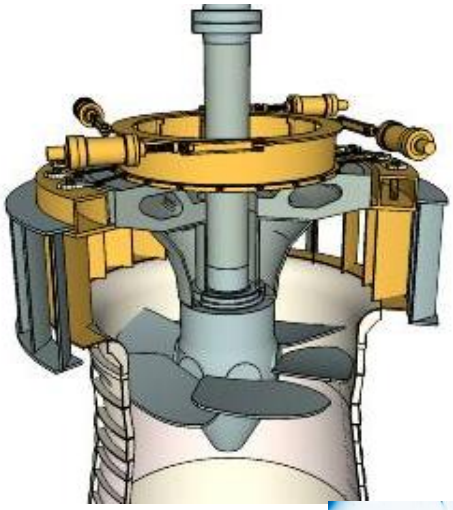
- Mining
- Lumber industry
- Agricultural machines
- Civil construction machinery

For these applications, the biodegradable fluids recommended are HEES, HETG and HEPR

For most industrial applications, HETG fluid is not recommended because in practice, the operating requirements are often not satisfied.

Activity 1.2 Real contact or interaction with water or mineral base residual oil:
Probability of real contact or interaction with water or mineral base residual oil according to practices level of maintenance and design parameters are defined in this activity.

WATER



HEPG

MINERAL OIL

- New design: usual commercial components
- New design: Components tested to operate with biodegradable fluids
- Redesign: fluid change = HEPR, HEES

Activity 1.3 International certificates (eco-label):

In this activity, the user's preference is requested to use biodegradable fluids with or without international certificates (eco-label).

Activity 1.4 Biodegradability and toxicity

In this activity the desired levels are appointed to the fluid for these characteristics according to OECD standards

- Biodegradability high level: > 70% (OECD 301B), all major product components tested separately
- Biodegradability medium level: > 60% (OECD 301B), product may be tested in one test

Activity 1.5 Ageing properties

This activity has the objective of defining the aging stability level of the fluids due to the oxidation stability, hydrolysis stability and anti-wear properties.

Activity 1.6 Viscosity grade

Viscosity grades ISO VG available for each biodegradable hydraulic fluid selected are recommended.

Operating temperature <20 ºC = Viscosity ISO VG 22
Operating temperature 20 ºC ≤ t_{op} ≤ 70 ºC = Viscosity ISO VG 32 e 46.
Operating temperature >70 ºC = Viscosity ISO VG 68.

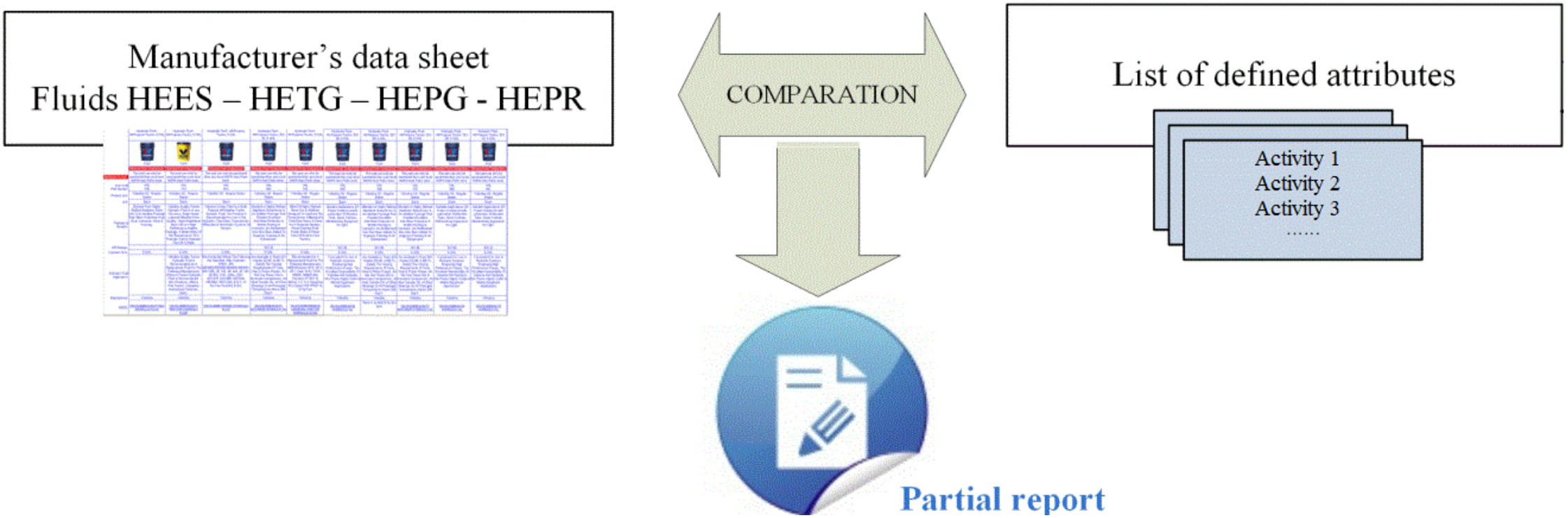
Seals compatibility with biodegradable fluids

	Viscosity grades ISO VG			
Fluid type	22	32	46	68
HEES	NBR FPM AU HNBR	NBR FPM AU HNBR	NBR FPM AU HNBR	FPM HNBR
HETG	NBR FPM AU HNBR	NBR FPM AU HNBR	NBR FPM AU HNBR	NBR FPM AU HNBR
HEPG	NBR FPM HNBR	NBR FPM HNBR	NBR FPM HNBR	FPM HNBR
HEPR	NBR FPM HNBR	NBR FPM HNBR	NBR FPM HNBR	NBR FPM HNBR

NBR: Nitrile Rubber or Buna-N
FPM (FKM): Fluorocarbon - Vitón
AU: Polyurethane
HNBR (HSN): Hydrogenated Nitrile

3.2 1st phase - Biodegradable fluid selection

Activity 1.7 A **partial report** with the biodegradable fluids selected



- Fluid type:
- Fluid name:
- Manufacturer:
- ISO viscosity grade available:
- Seal compatibility:
- Temperature limits:
- Environmental certification (ecolabel):

3.3 2nd phase - Selection of hydraulic components

2nd Phase: Selection of hydraulic components

- Design requirements obtained through interaction with the user (user requirements)

Activity 2.1 – Aplication circuit

Task 2.1.1

Industrial circuit:
- Reservoir
- Hydraulic pump
- Acumulator
- Heat exchange
- Actuation system
  - Cilinder
  - Directional valve
- Filters

Mobile circuit:
- Reservoir
- Hydraulic pump/motor
- Acumulator
- Heat exchange
- Actuation system
  - Cilinder
  - Directional valve
  - Valve blocks
- Filters

Activity 2.2 – Reservoir

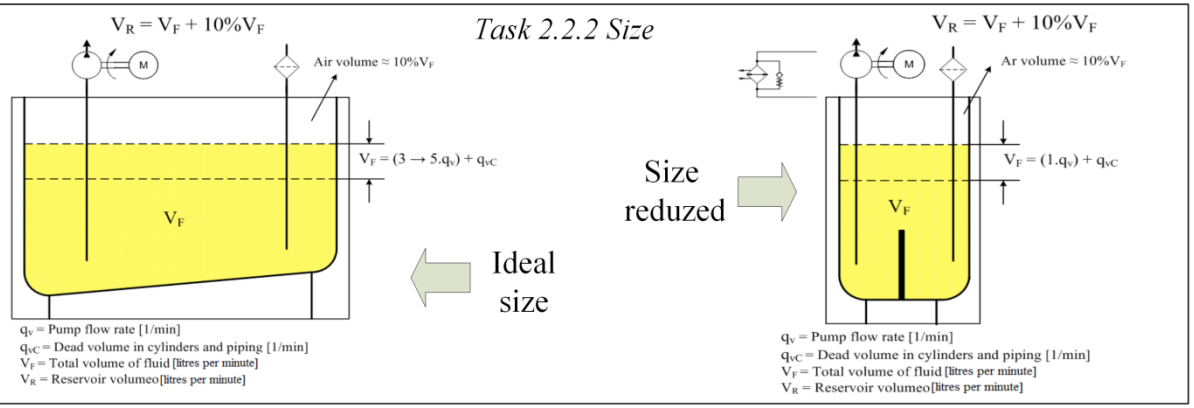
Task 2.2.1 Manufacturing material

Fluid	Materials manufacturing of hydraulic components					
	CS	SS	GS	AA	NAA	PLA
HEES	☺	☺	☺	☺	☺	☺
HEPG	☺	☺	☺	☺	●	○
HETG	☺	☺	☺	☺	☺	○
HEPR	☺	☺	☺	☺	☺	○

CS: Carbon steel
SS: Stainless steel
GS: Galvanized steel
AA: Anodized aluminum
NAA: Non-anodized aluminum
PLA: Plastics and composites

☺ Compatible
● Non-compatible
○ Compatible, but not recommended

Task 2.2.2 Size



e: Biodegradable fluid selection

Activity 2.1 Application circuit:

This activity defines the hydraulic circuit which brings an inherent list of components that will be selected in the following activities. The list of components related to this circuit are:

- Reservoir
- Heat exchanger
- Accumulator
- Filters
- Hydraulic pump/motor
- Actuation system

Activity 2.2 Reservoir:

The main requirements of the reservoir are defined according to the rules and recommendations, which are presented in eight tasks.

- Manufacturing material
- Reservoir size
- Reservoir/pump layout
- Reservoir form
- Pump inlet line and outlet line
- Baffles
- Diffusers
- Desiccant silica gel breathers.

Activity 2.2 Reservoir – Manufacturing material

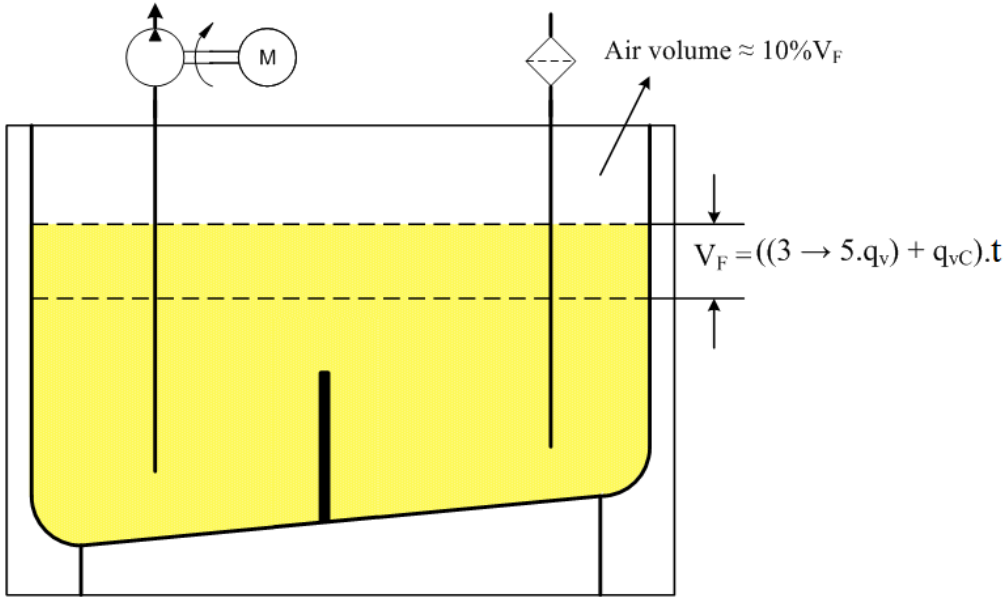
Fluid	Materials manufacturing of hydraulic components					
	CS	SS	GS	AA	NAA	PLA
HEES	☺	☺	☺	☺	☺	☺
HEPG	☺	☺	☺	☺	☻	◌
HETG	☺	☺	☺	☺	☺	◌
HEPR	☺	☺	☺	☺	☺	◌

CS: Carbon steel
SS: Stainless steel
GS: Galvanized steel
AA: Anodized aluminum
NAA: Non-anodized aluminum
PLA: Plstics and composites

☺ Compatible
☻ Non-compatible
◌ Compatible, but not recommended

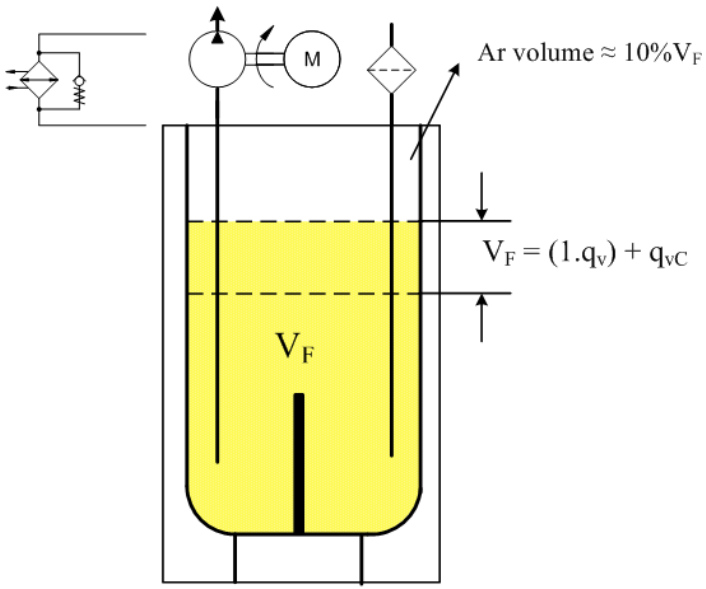
Activity 2.2 Reservoir – Reservoir size

$$V_R = V_F + 10\%V_F$$



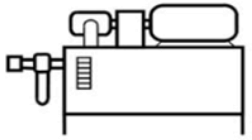
q_v = Pump flow rate [1/min]
q_{vC} = Dead volume in cylinders and piping [1/min]
V_F = Total volume of fluid [l]
V_R = Reservoir volumeo [l]
t =time [min]

$$V_R = V_F + 10\%V_F$$

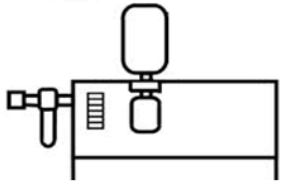


q_v = Pump flow rate [1/min]
q_{vC} = Dead volume in cylinders and piping [1/min]
V_F = Total volume of fluid [litres per minute]
V_R = Reservoir volumeo [litres per minute]

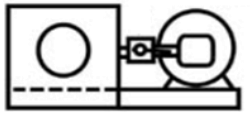
Activity 2.2 Reservoir – Reservoir/pump layout



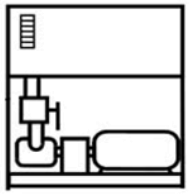
Pump and motor mounted on top of reservoir (horizontal)



Pump and motor mounted on top of reservoir (vertical)



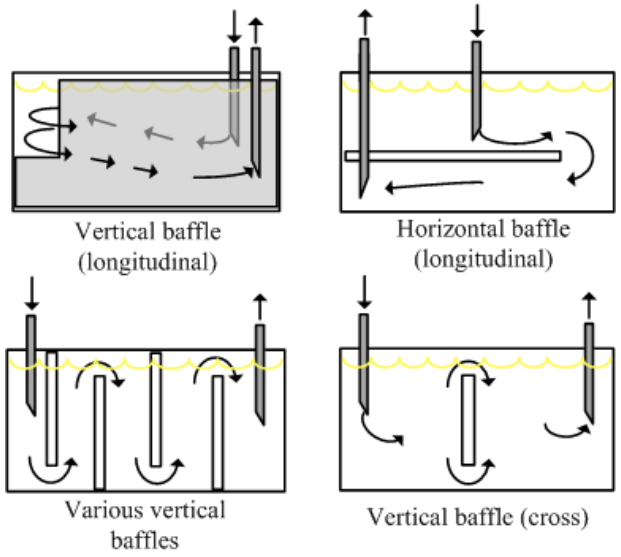
Pump and motor mounted alongside reservoir



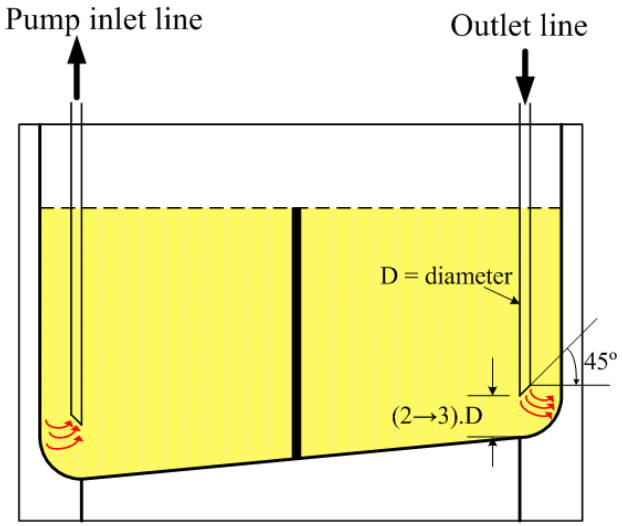
Reservoir located above pump and motor

Activity 2.2 Reservoir - Form

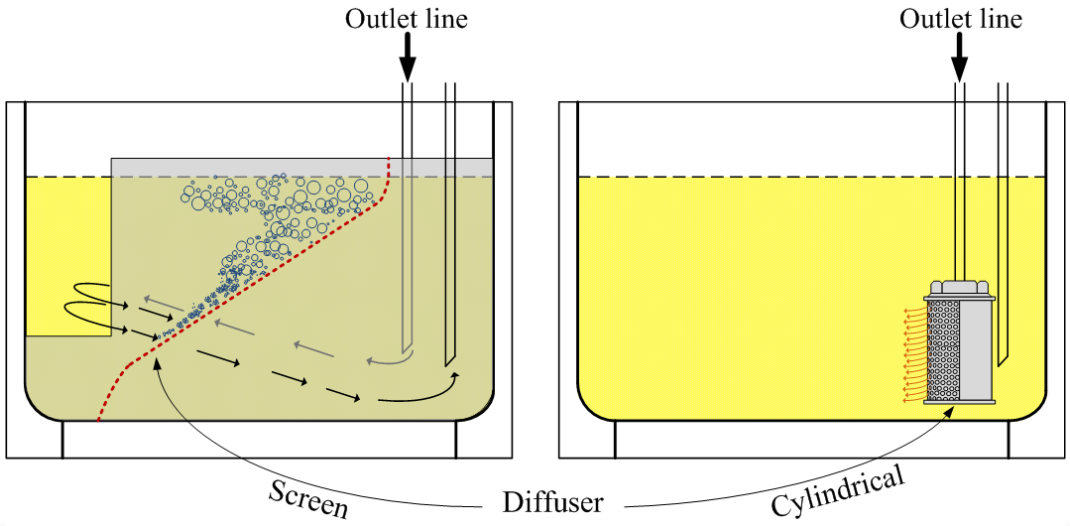
Activity 2.2 Reservoir - Baffles



Activity 2.2 Reservoir- Piping design

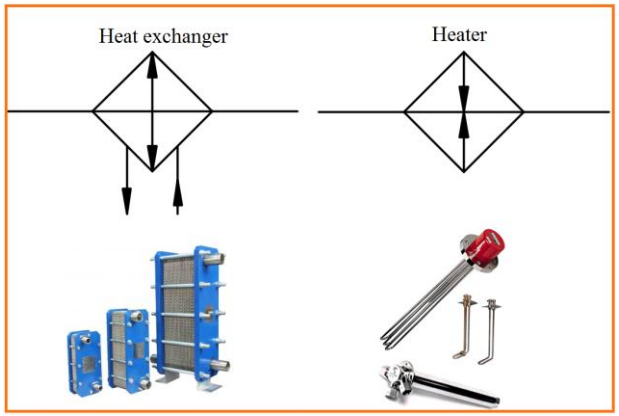


Activity 2.2 Reservoir- Diffuser



Activity 2.3 Heating and cooling devices

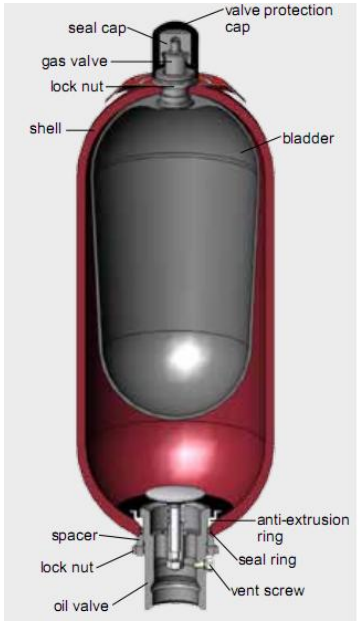
The rules which recommend using heating and cooling devices in the hydraulic system with biodegradable fluids are presented according to the operating temperature expected in the hydraulic system which was defined in the 1st phase.

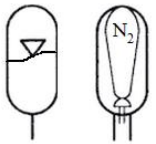


Activity 2.4 Accumulator

For applications of hydraulic systems using biodegradable fluids, it is recommended to use accumulators with separation between the air (Nitrogen) and the fluid,

It is recommended to use with the gas-loaded accumulator with separation for the bladder.

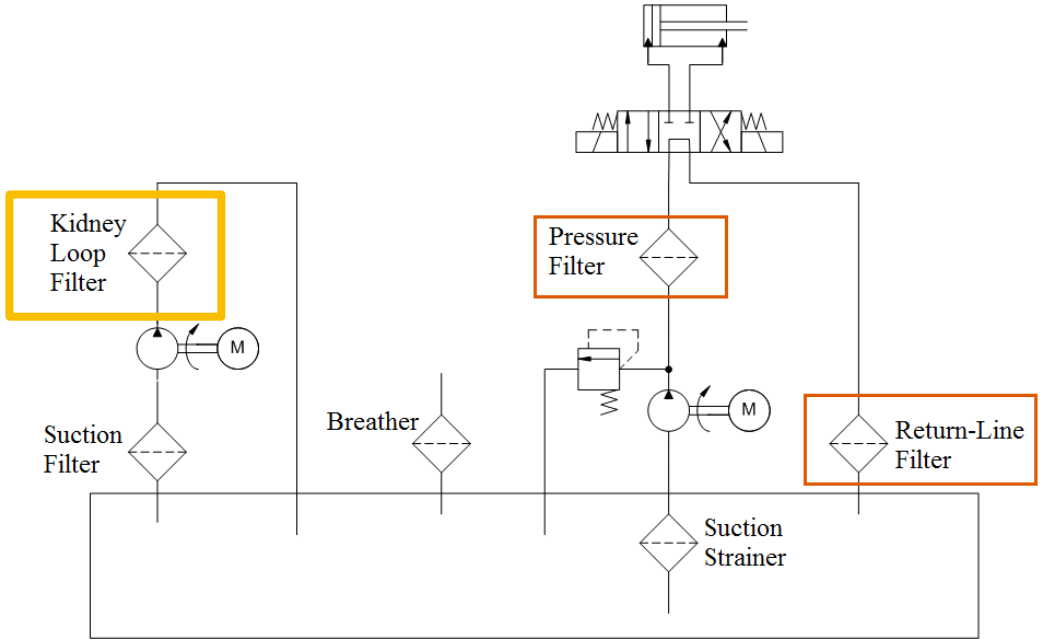




HYDAC (2012)

Activity 2.5 Filters

These criteria have to do with: types of filters (location), types of hydraulic filter media, ISO cleanliness recommendations from component manufacturers and filter efficiency.



Activity 2.5 Filters – Filter media type

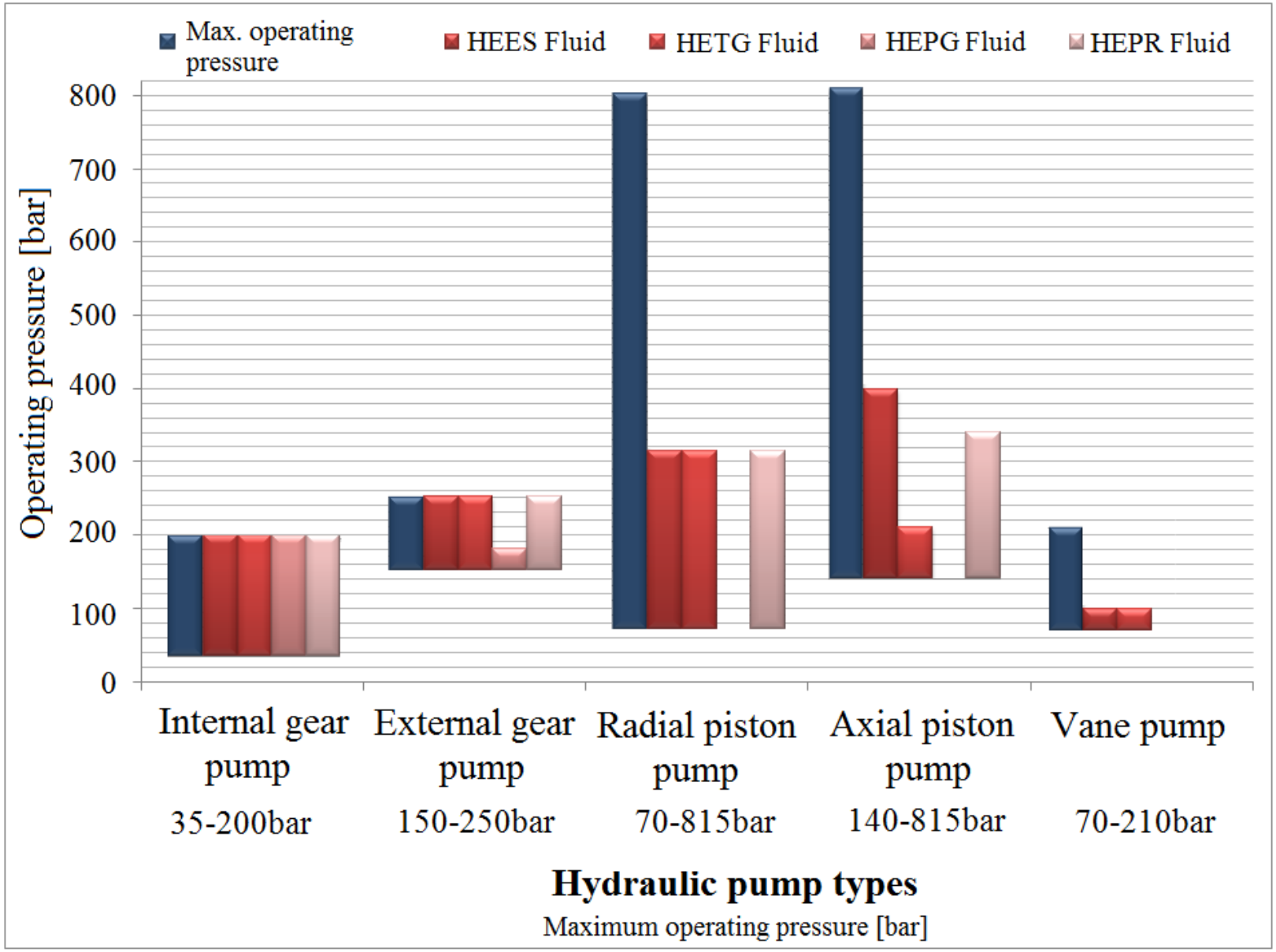
According to the compatibility between manufacturing materials and the biodegradable fluids defined in the 1st phase, the filter medias recommended are:

- Fiberglass
- Wire mesh

Activity 2.5 Filters – ISO cleanliness recommendations

Levels of cleanliness according to ISO 4406

Activity 2.6 Hydraulic pump/motor



Activity 3.1 Oil condition monitoring method

	Monitoring method	BASIC	ADVANCED
	Level of reliability	Acceptable	High
Measurement parameters (sensors)	Pressure	ONLINE	ONLINE
	Temperature	ONLINE	ONLINE
	Viscosity	Laboratory	ONLINE
	Solid particles counter	ONLINE	ONLINE
	Water content / relative humidity	Laboratory	ONLINE
	Dielectric constant	Laboratory	ONLINE
	Total number acid (TAN) / pH	Laboratory	Laboratory
	ICP Spectrometric Analysis	Laboratory	Laboratory

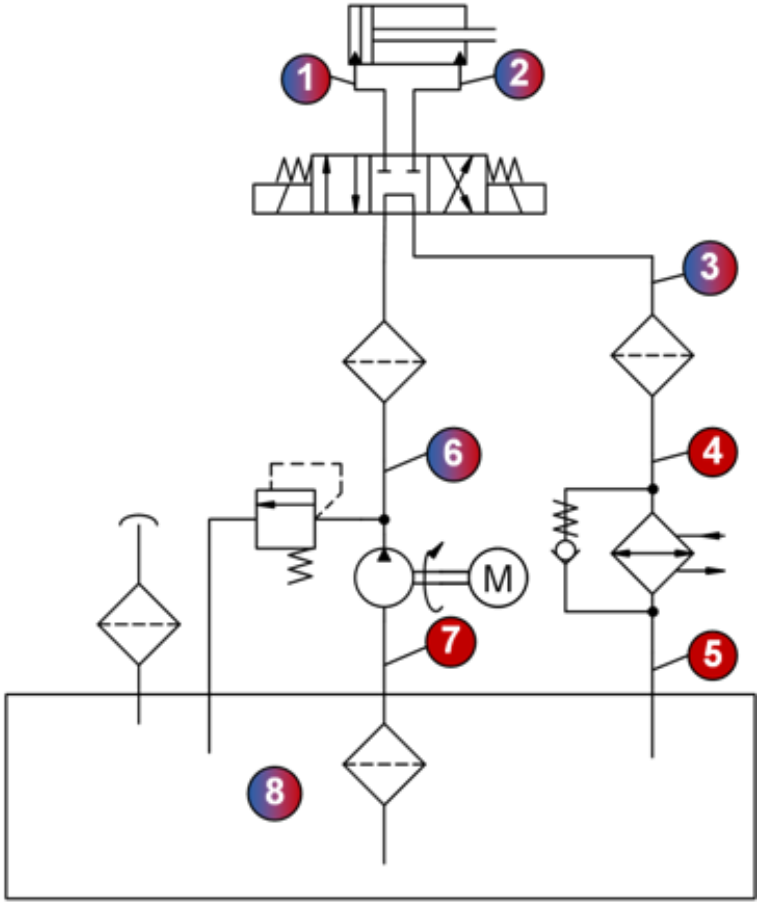
ONLINE Online monitoring Laboratory oil analysis

Basic: This method keeps the use of biodegradable fluids and guarantees an acceptable level of reliability of the hydraulic system.

Advanced: The use of **online** oil condition sensors together with appropriate **knowledge** of physicochemical changes in oil **allows** the user to have constant **overview** of the **oil quality** and its properties.

Activity 3.2 Monitoring points

Measurement parameters (sensors) / Monitoring point	1	2	3	4	5	6	7	8
Pressure	●	●				●	●	
Temperature	●	●		●	●			●
Viscosity			◐			◐		◐
Solid particles counter	◐	◐				◐		◐
Water content / relative humidity			◐			◐		◐
Dielectric constant			◐			◐		◐
Total number acid (TAN) / pH			●					●
ICP Spectrometric Analysis			●					●



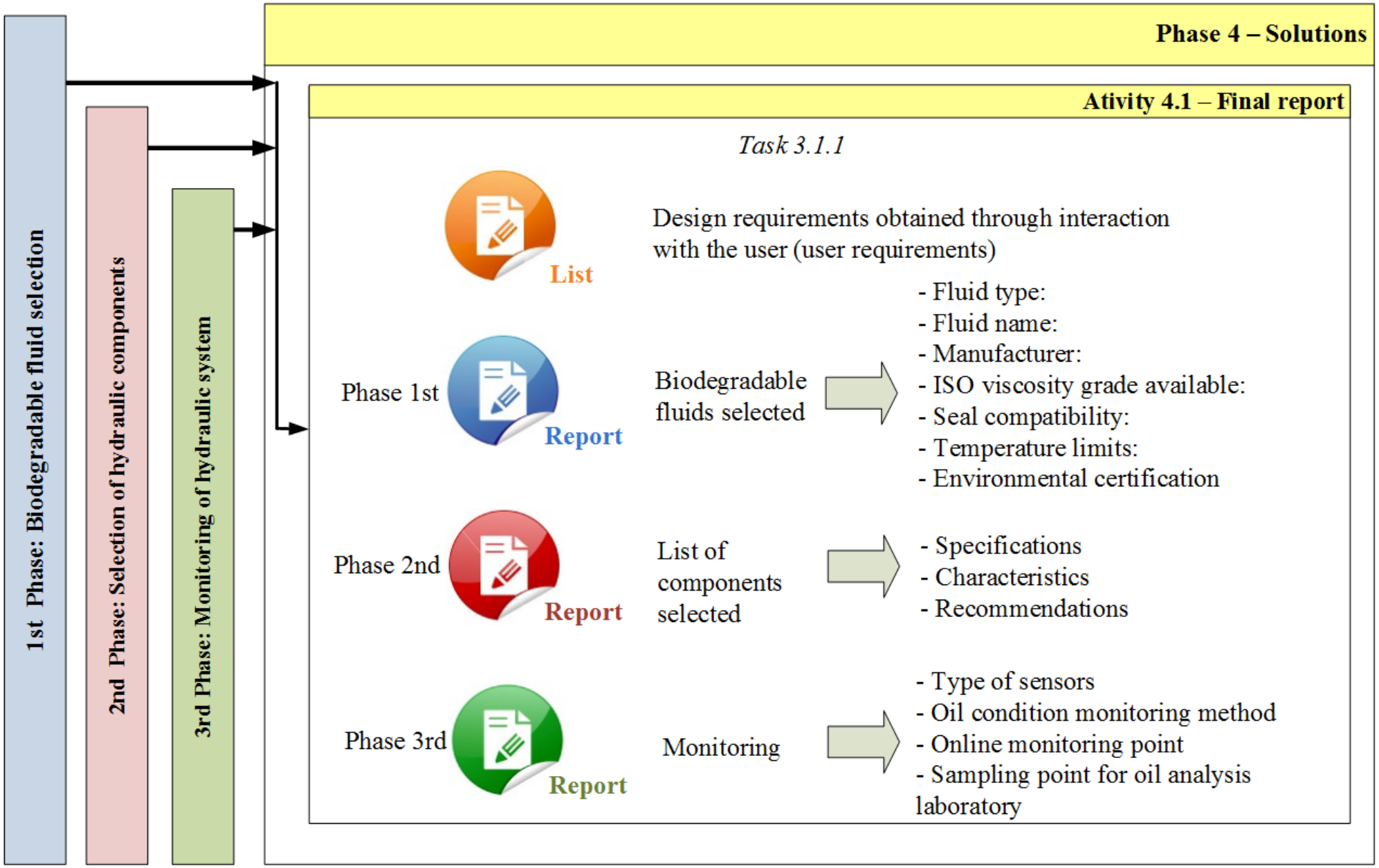
● Online monitoring point

◐ Online monitoring point and/or sampling point for oil analysis laboratory

● Sampling point for oil analysis laboratory

Possible points of fluid condition monitoring and sampling point to oil analysis in the laboratory

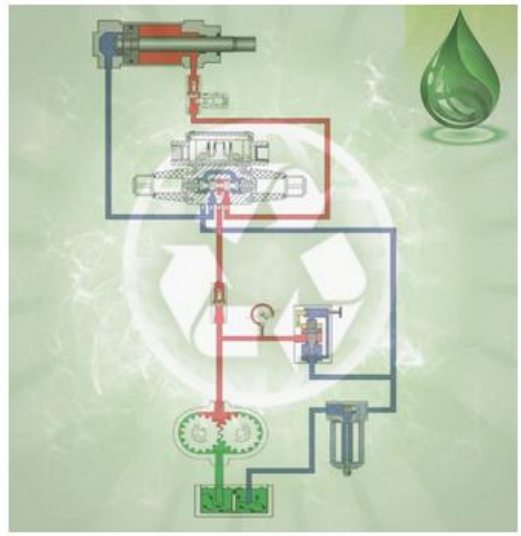
5.5 4th phase - Solutions



4. Expert System Prototype

Systematization of Hydraulic System Design with Biodegradable Fluids
SHBIO

FINAL REPORT

User answers	
1st. Phase:Biodegradable fluid selected	
2nd. Selection of hydraulic components	
3rd. Monitoring of hydraulic system	
Help	

Knowledge engineer: Yesid Asaff, Dr. Eng.
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Laboratory of Hydraulic and Pneumatic Systems - LASHIP
Federal University of Santa Catarina - Florianopolis, SC, Brazil

4.1 Expert System Prototype - Fluids

Fluid type: Hydraulic Oil Environmental Ester Synthetic - HEES
Fluid name: HLP Synth
Manufacturer: Panolin For more information click here
ISO viscosity grade available: (22 32 46)
Seal compatibility: (NBR FPM AU HNBR)
Temperature limits: -30°C to 90°C (reservoir), < 100°C locally in the system
Environmental certification (ecolabel): - Blue Angel: Alemanha - Korea Eco-label: Corea do sul

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Fluid type: Hydraulic Oil Environmental Ester Synthetic - HEES
Fluid name: Naturelle HF-E
Manufacturer: Shell For more information click here
ISO viscosity grade available: (32 46)
Seal compatibility: (FPM HNBR NBR AU)
Temperature limits: -30°C to 90°C (reservoir), < 100°C locally in the system
Environmental certification (ecolabel):No certification

Fluid type: Hydraulic Oil Environmental PolyGlycol - HEPG
Fluid name: Hydrosynth
Manufacturer: Avia For more information click here
ISO viscosity grade available: (22 32 46)
Seal compatibility: (FPM HNBR NBR)
Temperature limits: -30°C to 90°C (reservoir), < 100°C locally in the system
Environmental certification (ecolabel):No certification

2nd Phase: Selection of hydraulic components

- Application circuit
- Reservoir
- Heating and cooling devices
- Accumulator
- Filters
- Hydraulic pump/motor
- Actuation system

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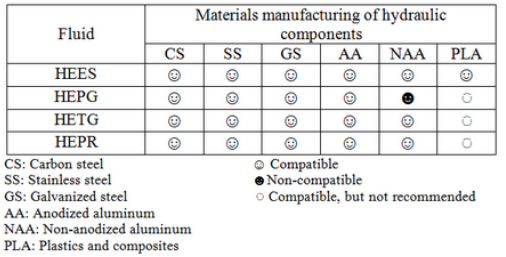
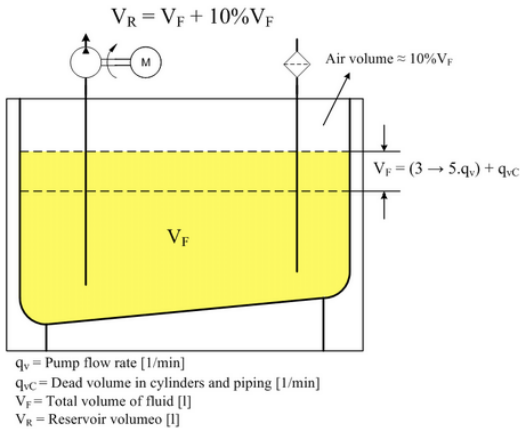
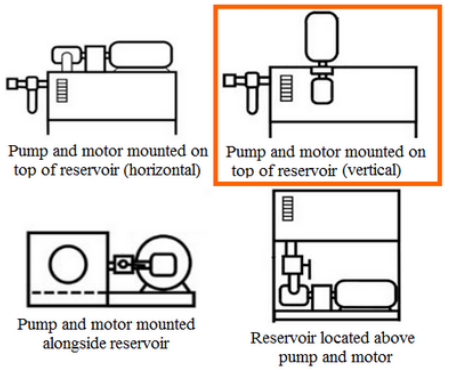
4.1 Expert System Prototype - Reservoir

RESERVOIR

Specification	Description
Manufacturing material in the reservoir These parameters that you set are applicable to manufacturing material of all hydraulic components selected in this phase, which is defined according to the compatibility with the biodegradable fluids selected in the 1st phase. According to biodegradable fluid selected on 1st phase, the **carbon steel** is a material compatible to use in the reservoir or any other on hydraulic component.	 Materials manufacturing of hydraulic components Fluid: HEES, HEPG, HETG, HEPR CS SS GS AA NAA PLA HEES: ☺ ☺ ☺ ☺ ☺ ☺ HEPG: ☺ ☺ ☺ ☺ ● ○ HETG: ☺ ☺ ☺ ☺ ☺ ○ HEPR: ☺ ☺ ☺ ☺ ☺ ○ CS: Carbon steel SS: Stainless steel GS: Galvanized steel AA: Anodized aluminum NAA: Non-anodized aluminum PLA: Plastics and composites ☺ Compatible ● Non-compatible ○ Compatible, but not recommended
Size of the reservoir This question solves the basic rules of dimensioning reservoir for industrial and mobile applications using biodegradable fluids. The application field that you selected on the 1st phase was a **Industrial** application field. ⇒ For industrial hydraulic systems there is a rule of thumb, where the fluid volume is between three and five times the pump flow rate per minute that provide pressure in the system. ⇒ For mobile hydraulic systems, the specification of a small reservoir can be required, which must be complemented for modifications that compensate the reduction of fluid volume. These compensations are: - Installation of a heat exchanger - High capacity filters - Use of baffles The rule of thumb related to sizing of reservoir for **Industrial** application field can be visualized in the figure on the right.	 $V_R = V_F + 10\%V_F$ M Air volume ≈ $10\%V_F$ $V_F = (3 \rightarrow 5.q_v) + q_{vC}$ V_F q_v = Pump flow rate [1/min] q_{vC} = Dead volume in cylinders and piping [1/min] V_F = Total volume of fluid [l] V_R = Reservoir volumeo [l]
Reservoir/pump layout **Pump and motor mounted on top of reservoir (vertical):** Current design trend has the electric motor mounted vertically, with the pump submerged in hydraulic fluid. This conserves space, because the reservoir can be made deeper and take up less floor space than one with traditional proportions. The submerged-pump design also eliminates external pump leakage, because any fluid leaking from the pump flows directly into the reservoir. In addition, the power unit is quieter, because the hydraulic fluid tends to damp pump noise.	 Pump and motor mounted on top of reservoir (horizontal) Pump and motor mounted on top of reservoir (vertical) Pump and motor mounted alongside reservoir Reservoir located above pump and motor

5. Conclusions

5.1 Conclusions

- State-of-the-art biodegradable fluids ➔ Lack of scientific and industrial information related to biodegradable fluids ➔ This work is a starting point in this country, in identifying new research and development of systems and/or environmentally friendly products.

- The introduction of a new line of research in the Brazilian scientific community, which is directed to the study and application of biodegradable fluids to be used in hydraulic systems.

- A list of new or modified design requirements of hydraulic systems were identified.

- Rules and recommendations for the selection of fluids and components were established ➔ heuristics knowledge acquired from experts, standards, literature and technical information.

- SHBIO's proposed focus on the systematization of procedures for specifying and analyzing the requirements of hydraulic systems in order to adapt and optimize the performance and component life, as well as the fluid itself ➔ Selection of fluids – Selection of components - Guidelines for monitoring

SYSTEMATIZATION OF HYDRAULIC SYSTEMS DESIGN FOR USE WITH BIODEGRADABLE FLUIDS

Thank you for your attention

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