CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The result from this study can be concluded as follows:

5.1.1 Technology aspects

1. Acid type, acid concentration, temperature, and retention time significantly effected the chemical leaching process.

2. Oxalic acid was suitable for chemical leaching of the silver coated on processed (used) radiographic film. It offered higher % SRE (Silver Recovery Efficiency) when compared with those of malonic acid and acetic acid.

3. The optimal conditions providing SRE> 97% , when 5 % (w/v) oxalic acid was used, were at 90°C, 60-minute retention time and at 100°C, 20-minute retention time. Characterizations on the sludge indicated that a metallic silver was present and no silver oxalate, an explosive material, was not found.

4. The proposed "chemical leaching by organic acid" technology in this study, when compared with the existing combustion process, was proven to be a "Green" technology due to the lower in the amount of CO_2 emissions.

5. The advantages and disadvantages of our proposed (organic acid leaching) technology and the available technologies (i.e., the existing combustion technology and the inorganic acid leaching technology) are tabulated in **Table 5-1**.

When temperature, toxicity, and other operating conditions, are considered; with respect to the operating phase, it is clear that all the methods give similarly excellent silver removal. However, oxalic acid leaching should be a preferable technique in terms of its toxicity and final product.

Table 5-1 Advantages and disadvantages of the proposed technology and the available silver removal technologies.

Criteria	Combustion technique	Acid leaching techniques	
		HNO_3 + Cyanide solution	Proposed method: Oxalic acid
Temperature (°C)	> 830	~ 70-80	~ 90-100
Operating condition	• High efficiency • Short retention time	• High toxicity • High efficiency • Short retention time	• Lower toxicity • High efficiency • Short retention time • Able to be reused
Emissions	• Large amount of CO_2 emissions • Wastewater • Solid waste	• Low CO_2 emissions • Acid vapor emission • Wastewater • Solid waste	• Low CO_2 emissions • Acid vapor emission • Wastewater • Solid waste
Product	• Sludge containing silver complexes and requires a smelting process	• Silver complexes, such as silver nitrate and silver cyanate, requires electrolysis as a further process.	• Sludge containing the silver element with gelatin makes the smelting process simple.

5.1.2 Management aspects

1. A material flow analysis was used for the investigation of the silver loss in the environment. I t was found that a considerable amount of silver had been released into the environment.

2. The weak points of the radiographic waste management system of Thailand were found to be among the waste generator, the waste dealer, the waste processor, and the waste regulator. Regulatory gaps and overlapping jurisdictions among government authorities resulted in the n on-systematic management of the waste. The release of pollutants mostly came from the unlicensed or small waste processor due to the lack of regulations and standards for their operations.

3. A fact sheet for the management of radiographic waste was developed. It proposed necessary measures and basic information to keep the radiographic waste from contributing to the on-going deterioration of the environment.

5.2 Recommendations and Future Works

The careful analysis of the experimental data led to the following recommendations. The ultimate intention is to encourage more attention in these areas in order to attain a successful implementation of effective practices of hazardous waste management.

From a technological point of view, retention time of chemical leaching process was found to be an important factor as the concentrations of silver varied with the retention time. It is, therefore, important to determine the reaction rate to find the proportional condition to be used for a design of a chemical reactor for industrial use.

1. The management part of the study identified the loop holes in the radiographic waste management in Thailand. The results from this research should be used as fundamental information for the concerned authorities to set up a system or, at least, to initiate a guideline for radiographic waste management.

2. One further concern is how to use our work and put it into practice. To scale-up the proposed technology, the following unit operations are to be considered.

Agitation:	circulation pump and mixer
Separation:	rotary filter and centrifuge or clarifier
Temperature:	heating unit or heat exchanger

The process could be explained as followed. Film sheets are cut by a shredder. The film chips are transferred to the reactor tank containing organic acid at defined concentration. The acid solution is heated by a heat exchanger and circulated by an anti-corrosive pump. After agitation the mixed liquor at 90°C and specified retention time, the leached film chips are filtered out of the mixed liquor and rinsed with clean water. The residual liquor is further centrifuged to separate solids or clarified to settle sludge. A proposed configuration of the leaching system is drawn as shown in **Figure 5-1**. When the temperature was heat up to 100°C, an air cooler was required as demonstrated in **Figure 5-2.**

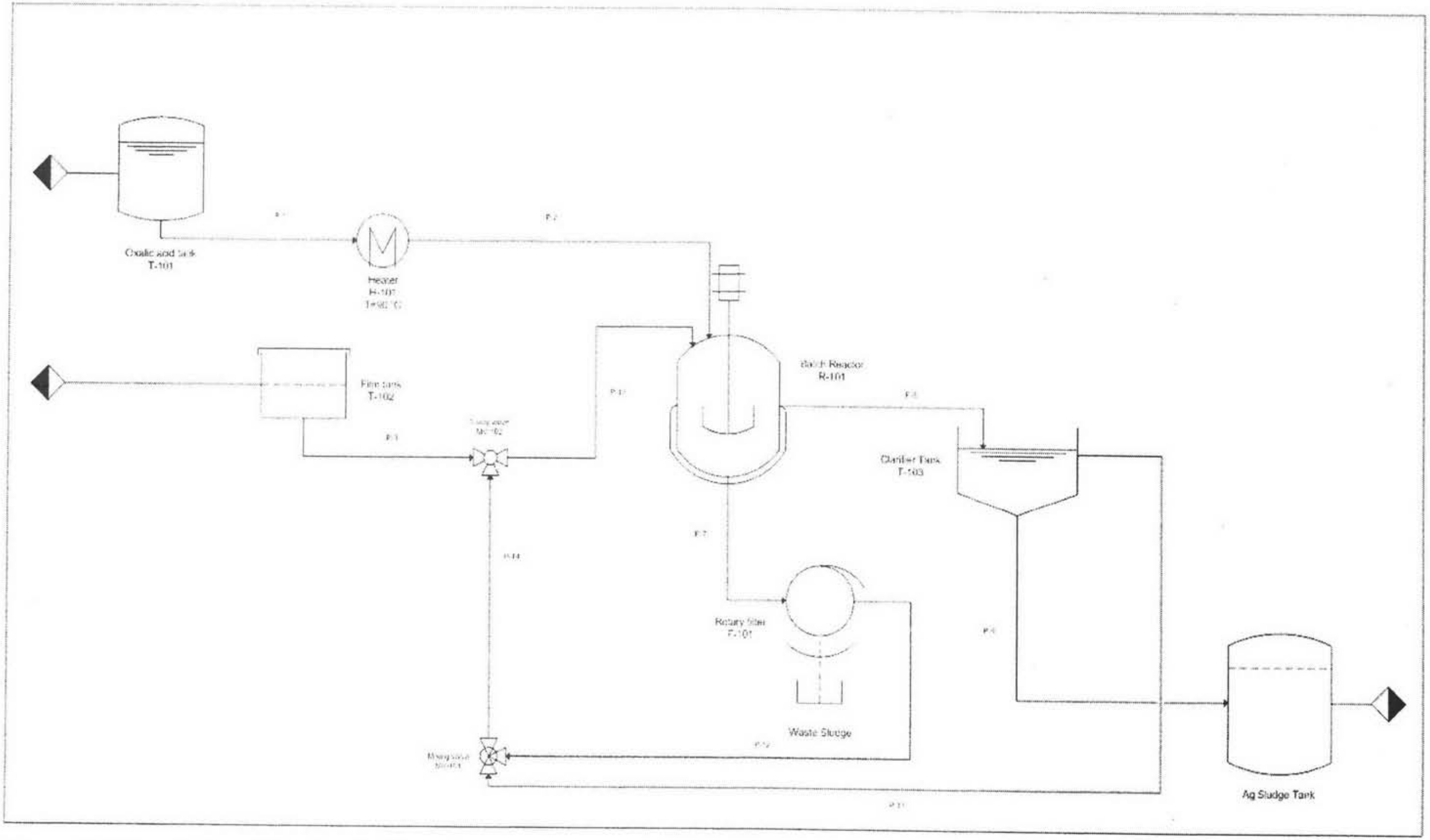

Figure 5-1 Plant design of the chemical leaching process using 5% (w/v) oxalic acid at 90°C, 60-minute retention time.

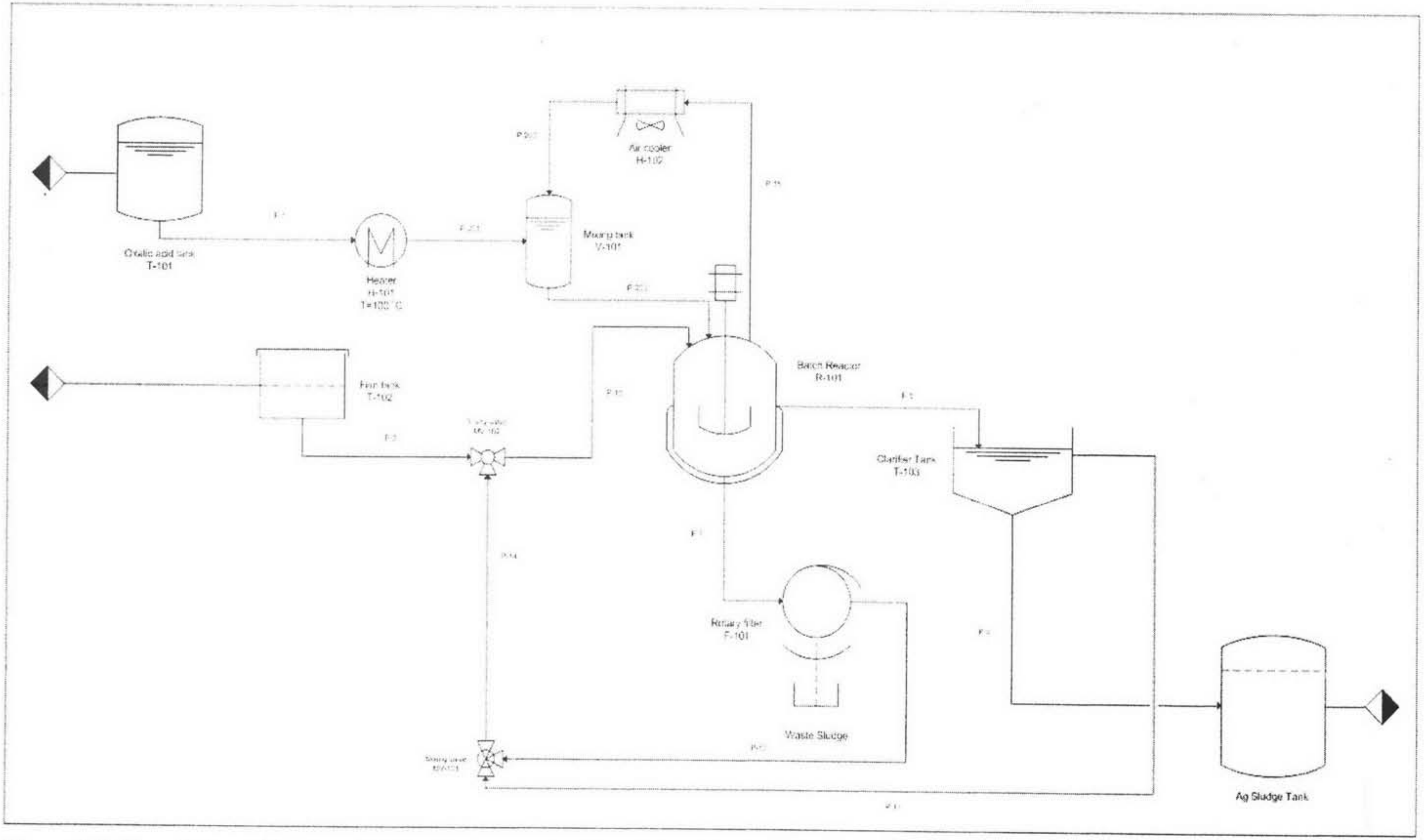

Figure 5-2 Plant design of the chemical leaching process using 5% (w/v) oxalic acid at 100°C, 20-minute retention time.