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# Evaluation of thermal hazards in phenol-formaldehyde polymerization

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ABSTRACT

Petrochemical plants have been manufacturing **phenol-formaldehyde resins** for a long time, and over the years, many accidents have resulted from **runaway reactions**, sometimes with serious consequences. In this study, we used **differential scanning calorimetry (DSC)** and exacting measurements of pH conditions to investigate the basic characteristics of **thermal polymerization**. Careful laboratory examination of the processes, as well as a thorough survey of the accidents that have occurred in the past, led to the development of several **reactivity accident prevention methods** that can be employed to eliminate hazards associated with phenol-formaldehyde resin manufacture. Kinetic parameters, as well as prevention, are discussed in depth. Attention is drawn to the hazardous characteristics of various stages of manufacture, which should be of value in preventing these types of accidents in the future. This study is expected to be valuable to workers in chemical plants where phenol-formaldehyde resins are manufactured and processed.



## 1. Introduction

Taiwan is a world leader in the production of many important petrochemical products. However, the hazardous nature of some of the wide range of different chemicals used, combined with inadequate control of production procedures, can lead to serious accidents. Phenol-formaldehyde (PF) resin is a solid that may be colorless and transparent or yellow to brown and is most frequently used in electrical equipment. These resins are colloquially referred to as Bakelite. PF resins are widely employed in the manufacture of circuit boards and adhesives and are made by the condensation of phenol ($C_6H_5OH$) and formaldehyde (HCHO). These PF resins are excellent electrical insulators, have good thermal and flame resistance, and are waterproof and resistant to acids. However, they have lower resistance to bases. PF resins, which may be thermosetting or thermoplastic, have good mechanical properties and can be machined and cut quite easily. Phenol and formaldehyde undergo polymerization in either acid- or base-catalyzed reactions to form PF resin and water. The chemical composition can be modified during synthesis to obtain different properties, such as increased resistance to bases, oil, or corrosion, as well as mechanical resistance to wear. We try to understand the hazardous characteristics of PF resin in this study. And, this study was the first time changed pH and added difference materials for evaluating the exothermic reactions.

The objective of this study was to collect information on the manufacture of PF resins and conduct a general survey of the hazardous properties of processes used for the manufacture of PF resins. We established the exothermic properties of many different PF resins to assess reaction kinetics, safety parameters, and the likelihood of runaway reactions. We also gained an understanding of the manufacturing methods. Our results will be available to such entities as fire departments and manufacturers as a reference for improvement. The aim of this work is to establish comprehensive industrial safety measures as well as to build public confidence with respect to chemical manufacturing processes. We carried out systematic analyses of PF resin manufacture to thoroughly assess potential runaway reactions and the resulting hazards and to

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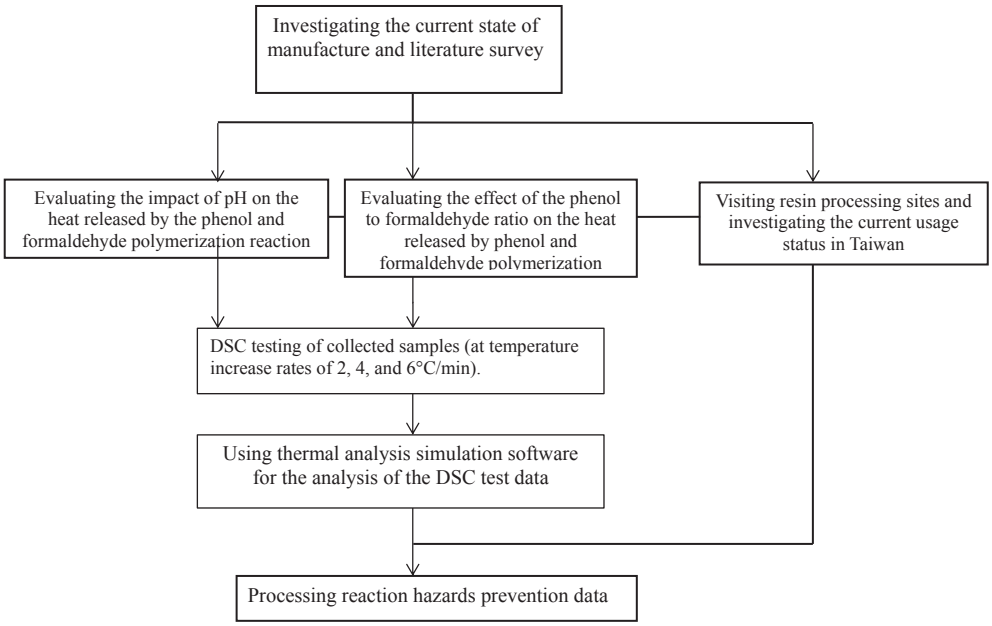


**Fig. 1.** Investigation flow chart (1).

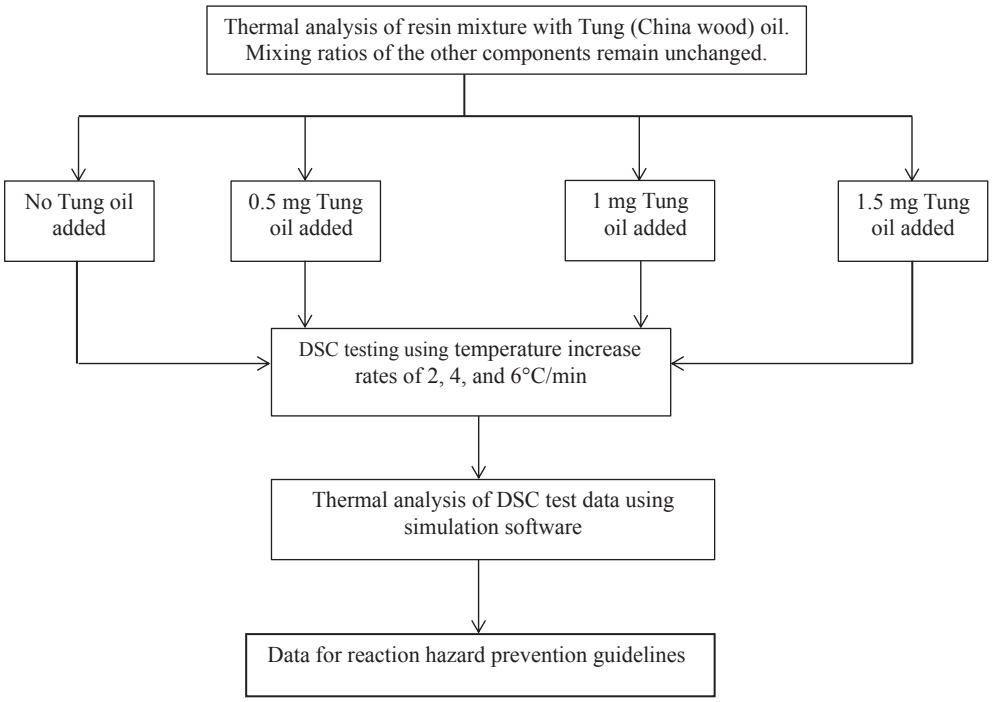


**Fig. 2.** Investigation flow chart (2).

achieve a better understanding of the most hazardous stages of manufacture. This will help identify the most effective emergency response and improvement strategy and will also help with the design of an effective control system. We hope that these measures will make a meaningful contribution to the development of a safe manufacturing process.

The chemical reaction is as shown below:

$$nC_6H_5OH + nHCHO \rightarrow [C_6H_3OHCH_2]n + nH_2O$$

Phenol and formaldehyde are mixed, and sodium acetate is then used as a catalyst to generate PF resin. This method is similar to that used to make urea-formaldehyde resins. Some common raw materials include phenol, resorcinol, cresol, xylenol, para tert-butyl- or para phenyl-phenol, formaldehyde, and furanic compounds. The production process includes two steps, condensation and

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