GHARDA FOUNDATION
GHARDA FOUNDATION'S
GHARDA INSTITUTE OF TECHNOLOGY
(Approved by AICTE New Delhi, Recognised by DTE Maharashtra State and Affiliated to University of Mumbai)
GIT GHARDA INSTITUTE OF TECHNOLOGY
CAREERS360 Rating - A A +
A/P - Lavel, Tal - Khed, Dist - Ratnagiri. Pin - 415 708, M.S.Tel. : 02356 - 273134, Fax : 02356 - 262980
Email : info@git-india.edu.in Website : www.git-india.edu.in

Advanced Reactive System Screening Tool (ARSST)

1. Introduction

The **Advanced Reactive System Screening Tool (ARSST)** is a low thermal inertia calorimeter developed by Fauske & Associates, Inc. for evaluating reactive chemical hazards and obtaining critical process safety data. It is widely used in chemical, pharmaceutical, petrochemical, and research industries to investigate runaway reactions, thermal decomposition, gas generation, and emergency relief requirements.

Safe process design requires accurate knowledge of reaction kinetics, heat release rates, pressure generation rates, and decomposition characteristics of chemicals under abnormal operating conditions. ARSST provides this information using a small sample size while maintaining near-adiabatic conditions. The instrument is considered a practical and cost-effective tool for preliminary hazard assessment and emergency relief system design.

2. Working Principle of ARSST

The ARSST operates on the principle of **adiabatic calorimetry**, where heat generated by a chemical reaction remains within the system and is not lost significantly to the surroundings. This enables accurate measurement of self-heating and pressure rise during a runaway reaction.

A small quantity of sample (typically 5–10 mL) is placed in a lightweight glass test cell. The test cell is located inside a stainless-steel containment vessel equipped with pressure and temperature measuring instruments.

The sample is heated at a controlled rate using an external heater. As the temperature increases, any exothermic reaction occurring within the sample generates heat. The ARSST continuously monitors:

- Temperature of the sample
- Pressure inside the containment vessel
- Rate of temperature rise (dT/dt)
- Rate of pressure rise (dP/dt)

When self-heating begins, the instrument automatically switches to adiabatic tracking mode. In this mode, the heater supplies only the amount of energy required to compensate for heat losses, allowing the reaction to proceed under nearly adiabatic conditions.

The resulting temperature and pressure histories are used to determine reaction kinetics, thermal stability, gas generation rates, and vent sizing requirements.

ARSST Components

The Advanced Reactive System Screening Tool (ARSST) consists of several key components designed to accurately evaluate thermal hazards and runaway reaction behavior. The primary element is a 10 mL spherical glass test cell, which holds the sample under investigation. This test cell is enclosed by a bottom-heater jacket and thermal insulation that provide controlled heating during experiments. Temperature and pressure changes are monitored using thermocouples and a pressure transducer, respectively.

The test cell assembly is housed within a 350 mL stainless-steel containment vessel, which serves two important functions: it acts as a pressure simulator for experimental studies and as a safety vessel to contain any hazardous reactions. An optional immersion heater can also be used when required for specific testing conditions.

To ensure uniform mixing of the sample, a small magnetic stir bar is placed inside the glass test cell and driven by an external magnetic stirrer. The external bottom heater is directly attached to the test cell and functions similarly to the dual-bottom-heater arrangement used in the earlier RSST design. The heater system is connected in series, providing an overall electrical resistance of approximately 24 Ω.

One of the most significant features of the ARSST is its very low thermal inertia, which is characterized by a phi-factor (ϕ) of approximately 1.04. This indicates that the heat capacity of the apparatus is very small compared to that of the sample, allowing the experiment to closely simulate adiabatic conditions. As a result, the measured temperature and pressure data accurately represent the behavior of the reaction at full process scale, making the ARSST a valuable tool for process safety analysis and emergency relief system design.

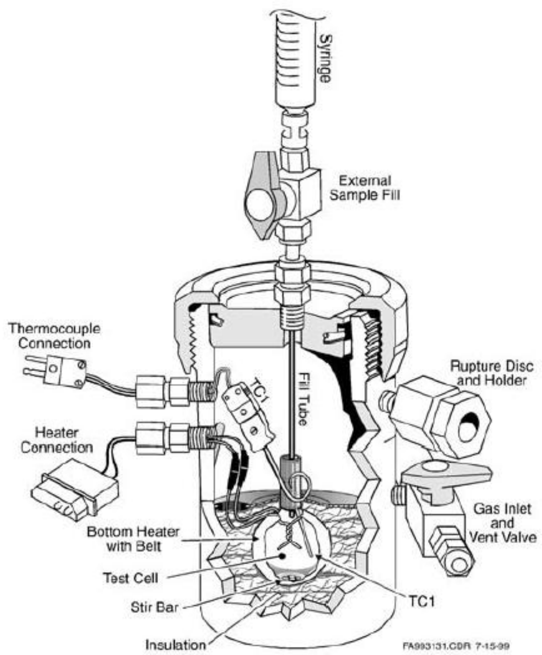

Figure 1. Schematic of containment vessel and internals.

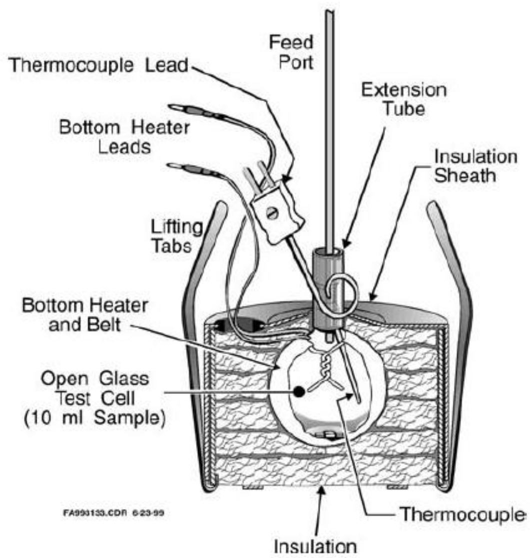

Figure 2. Test cell assembly.

Operating Procedure of ARSST

The operation of ARSST involves a systematic sequence of steps to ensure accurate and safe measurement of thermal hazards.

Step 1: Sample Preparation

A representative sample of the chemical mixture is prepared.

Typically 5–10 mL of material is used.

The sample is loaded into the glass test cell.

A magnetic stir bar may be inserted if agitation is required.

Step 2: Assembly of Test Cell

The glass cell is placed inside the stainless-steel containment vessel.

Thermocouples and pressure sensors are connected.

The containment vessel is sealed.

Step 3: Application of Inert Gas Pressure

Nitrogen is introduced into the vessel.

Back pressure is applied to suppress premature boiling.

Typical pressures range from 200–300 psi.

Step 4: System Calibration

Temperature and pressure sensors are calibrated.

Heater performance is verified.

Baseline measurements are recorded.

Step 5: Controlled Heating

The sample is heated using Dynamic Scan Mode

The sample is heated continuously at a constant heating rate.

Step 6: Detection of Exothermic Activity

When the sample begins to self-heat:

Temperature rise rate increases.

Pressure generation may occur.

The system automatically tracks the reaction under adiabatic conditions.

Step 7: Data Collection

The following data are recorded continuously:

Temperature

Pressure

Self-heating rate

Pressure rise rate

Heat release characteristics

Step 8: Data Analysis

The software calculates:

Adiabatic temperature rise (ΔT_{ad})

Time to Maximum Rate (TMR)

Heat of reaction

Reaction kinetics

Gas generation rates

Step 9: Cooling and Cleanup

After completion:

The system is cooled.

The containment vessel is depressurized.

Residues are safely removed.

Equipment is cleaned for subsequent tests.

Applications in Chemical Engineering

ARSST has become one of the most important laboratory tools in chemical engineering because it provides critical information required for process development and scale-up.

4.1 Reaction Hazard Screening

The instrument rapidly identifies whether a reaction is:

Safe

Potentially hazardous

Capable of thermal runaway

This information is valuable during process development.

4.2 Thermal Stability Assessment

ARSST determines:

Decomposition temperature

Onset temperature

Self-heating behaviour

4.3 Kinetic Analysis

The instrument provides data for determining:

Activation energy

Reaction rate constants

Arrhenius parameters

which are essential for reactor design and simulation.

ARSST provides:

Energy release rates

Gas generation rates

Pressure rise rates

which are used in DIERS vent sizing calculations.

Gas Generation Studies

For decomposition reactions producing non-condensable gases, ARSST quantifies:

Gas evolution rates

Pressure build-up

Venting requirements

The Advanced Reactive System Screening Tool (ARSST) is an essential calorimetric instrument for thermal hazard assessment and process safety analysis. Its low thermal inertia, small sample requirement, and ability to simulate realistic process upset conditions make it highly valuable in chemical engineering research and industrial applications. ARSST provides critical information such as adiabatic temperature rise, pressure rise rate, gas generation rate, reaction kinetics, and emergency relief requirements. Consequently, it serves as a powerful tool for identifying reactive hazards, preventing runaway reactions, designing safer processes, and ensuring regulatory compliance in modern chemical industries.