

**ENHANCING THE MEASUREMENT ACCURACY OF THERMOSTATS
AND DRYING CABINETS.**

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Abstract: This thesis is dedicated to enhancing the metrological control of thermostats and drying cabinets. Based on an analysis of existing standards (GOST, ISO, O‘zDSt), shortcomings were identified, and new methods (multi-point calibration, digital sensors) were developed. The scientific novelty lies in the normative projects and IoT integration. The practical significance is in increasing measurement accuracy and ensuring safety.

Keywords: metrology, thermostat, drying cabinets, calibration, temperature control, standardization, sensors, uncertainty, improvement, normative documents.

In contemporary scientific research laboratories, medical diagnostic centers, pharmaceutical enterprises, and diverse industrial sectors, thermostats and drying cabinets stand as pivotal heat-processing apparatuses. These devices maintain precise temperatures, facilitate sample drying, sterilization, and stable chemical reactions, ensuring the integrity of experimental outcomes. The reliability of parameters such as temperature accuracy, uniformity, and stability directly influences result quality, underscoring the imperative for rigorous metrological oversight. As measurement instruments, these cabinets must undergo mandatory verification to align with national and international standards. In Uzbekistan, recent advancements in metrological infrastructure—harmonization with global norms, certification, and calibration—have accelerated, yet persistent gaps in regulatory frameworks, verification techniques, and technical infrastructure hinder comprehensive efficacy in assessing thermal equipment precision.

The urgency of this domain stems from the profound impact of measurement accuracy on laboratory reliability, process safety, and product quality. Adherence to



metrological standards not only bolsters production credibility but also elevates compliance with international benchmarks. This thesis synthesizes theoretical underpinnings, critiques extant normative documents and verification protocols, and proposes methodological enhancements, drawing on analytical reviews, comparative studies, mathematical statistics, and experimental validations. Its novelty lies in formulating novel verification methodologies, recommending advanced testing protocols, and laying groundwork for updated normative-technical drafts. Practically, these innovations promise to refine metrological provisioning, augment measurement fidelity, and foster safer, more efficient thermal operations.

Thermostats and drying cabinets fulfill critical roles across technological landscapes. Hot plates, for instance, heat samples to 350–400°C via open or closed heating coils, ideal for thermal preparation in distillation or sand baths, with open coils suiting non-volatile substances for easy replacement and closed variants enhancing safety for flammable materials. Water baths, regulated from 30–100°C, support heating, evaporation, drying, and extraction using microprocessor controls and distilled water fills, demanding meticulous maintenance to avert contamination—filling to two-thirds capacity, post-use drainage, and repeated rinsing. Drying ovens, operational from 40–250°C with $\pm 5^\circ\text{C}$ tolerance, sterilize glassware, metals, and oils in microbiology, featuring perforated shelves for convective airflow and electronic regulators for precise regime setting. Prohibitions on aggressive reagents underscore safety imperatives.

Thermostats, precision-maintaining at $\pm 0.1^\circ\text{C}$ from 20–80°C, incubate microbial cultures in perforated metal racks within insulated chambers, barring cracked vessels to prevent hazards. Autoclaves employ pressurized steam for sterilization, with components like pressure gauges, safety valves, and steam inlets ensuring controlled cycles: water filling, material loading, secure latching, air expulsion via venting, pressure buildup to nominal levels (e.g., 0.1 atm offsets), and post-cycle cooldown. Centrifuges separate heterogeneous liquids via centrifugal force at 1500–3000 rpm, requiring balanced tubes and gradual acceleration to avoid vibrations. Microcentrifuges handle microliter volumes up to 17,000 rpm at -11–40°C using Eppendorf tubes. Magnetic stirrers agitate reagents at 100–1500 rpm via rotating magnetic bars, often with heating for multi-flask setups. Shakers and incubator-shakers enable orbital



mixing up to 500 rpm, with temperature control from 5–80°C for cell cultivation and extraction.

Drying cabinets, structurally robust with stainless-steel chambers, rubber seals, and ventilation fans, incorporate signal indicators for power, heating, alarms, and overheat warnings. Control panels feature menu navigation, parameter editing, and power toggles, interfacing with thermostats to modulate heating elements. Metrological assurance underpins these systems, ensuring uniformity, traceability, and observability per ISO, OIML, GOST, and O'zDSt standards. Core principles include standardized etalons, validated calibration chains, and rigorous monitoring of errors, uncertainties, repeatability, hysteresis, and stability. Measurement tools must delineate systematic, random, instrumental, and environmental error sources, adhering to state standards, international guidelines, and operational manuals.

Automatic control architectures, modeled via functional diagrams, integrate controlled objects (e.g., cabinet air), sensors (thermistors), setters (rheostats), comparators (Wheatstone bridges), amplifiers, actuators (electromagnets), and correctors. Signal graphs and differential equations capture dynamics: bridge unbalance voltages, amplified currents driving magnetic fluxes, forces on dampers, pressure-volume relations in cylinders, power dissipation in heaters, and heat fluxes yielding air temperatures. Linearization around nominal points—assuming small deviations and smooth functions—yields operator-form transfer functions, quantifying time constants and gains for stability analysis. Perturbations like supply voltages, ambient pressures, and temperatures necessitate feedback loops to sustain equilibrium, where heaters counterbalance radiative losses.

Uzbek and international standards impose stringent requirements on these devices. O'zDSt 8.009–2016 outlines calibration and testing sequences, while O'zDSt ISO/IEC 17025 ensures laboratory competence. GOST 30429–2014 mandates multipoint calibrations and stability metrics, ISO 13528 provides statistical proficiency testing, and IEC 61010 governs electrical safety. However, deficiencies abound: O'zDSts lack specificity for uniformity thresholds and multipoint mandates; GOSTs overlook IoT and digital sensors; ISO variants inadequately adapt to thermal rigs. Current verification protocols—visual inspections (detecting 40–45% faults in insulation, seals, and electrics), single-point calibrations (swift but uniformity-blind), multipoint mappings

(comprehensive yet time-intensive per ISO 17025), and dynamic stability tests (real-time fluctuations)—yield average errors of $\pm 0.2\text{--}0.5^\circ\text{C}$ for accuracy, $0.5\text{--}1.8^\circ\text{C}$ for uniformity, and $0.1\text{--}0.3^\circ\text{C}$ for stability. Compliance hovers at 85–90%, but legacy models falter, exacerbated by Class B sensors, absent data-logging, and incomplete GUM uncertainty propagation.

Shortcomings in normative documents include undefined uniformity minima, optional multipoint testing, lax digital sensor specs, undefined recalibration intervals, and omissions for PID controllers, airflow velocities, energy efficiency, filtration hygiene, and local manufacturing regs. Harmonization gaps with IEC safety and ISO GUM persist, alongside unaddressed innovations like smart sensors.

To ameliorate these, novel verification methodologies emphasize accuracy (systematic errors from gradients and inertia), uncertainty (GUM-compliant A/B-type combining statistical dispersions and a priori bounds, yielding expanded $U = k \cdot u_c$ with $k=2$), and repeatability (≥ 30 replicates at steady-state, via variation coefficients). Spatial uniformity demands 9–12 sensors across triplanar grids for 3D heat maps, identifying hotspots and convection deficits against $\pm 0.5\text{--}1.0^\circ\text{C}$ norms. Dynamic stability assesses ramp rates, overshoots, and oscillations in programmed cycles, incorporating time constants and phase lags.

Advanced technologies propel oversight: thermocouples (K/J/N types for $0\text{--}1200^\circ\text{C}$ breadth), RTDs (Pt100/1000 for $\pm 0.01\text{--}0.05^\circ\text{C}$ linearity and longevity), digital sensors (DS18B20/TMP117 for noise-immune, self-diagnosing outputs), and fiber-optic variants (EMI-proof, $\pm 0.05^\circ\text{C}$ in hazardous environs). Microprocessor/PLC systems enable real-time PID tuning, drift compensation, and multi-zone heating. Calibration via dry-block ($\pm 0.01^\circ\text{C}$ stability) or liquid baths ($\pm 0.005^\circ\text{C}$) uses traceable etalons; IR non-contact aids validation. IoT integrates Wi-Fi/ZigBee for cloud-logging and alerts, while AI predicts drifts via pattern analysis, optimizing energy via dual-loop controls and insulation.

Drafting new normative-technical documents begins with gap analyses, grounding in CFD simulations, statistical validations, and stakeholder inputs. Structures encompass scopes, technical specs (diapasons, classes), verification protocols (multipoint, automated), safety/efficiency clauses, and appendices (diagrams, algorithms). Aligning with ISO 9001/17025 and GOST, they mandate Class A sensors,

GUM uncertainties, data-loggers, and annual recalibrations, trialed in pilots for refinement. These foster innovation—AI/IoT standardization—while prioritizing user-centricity for practical uptake.

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