Measuring Up

Tools for High Performance Building Performance

RESNET 2008

San Diego, CA

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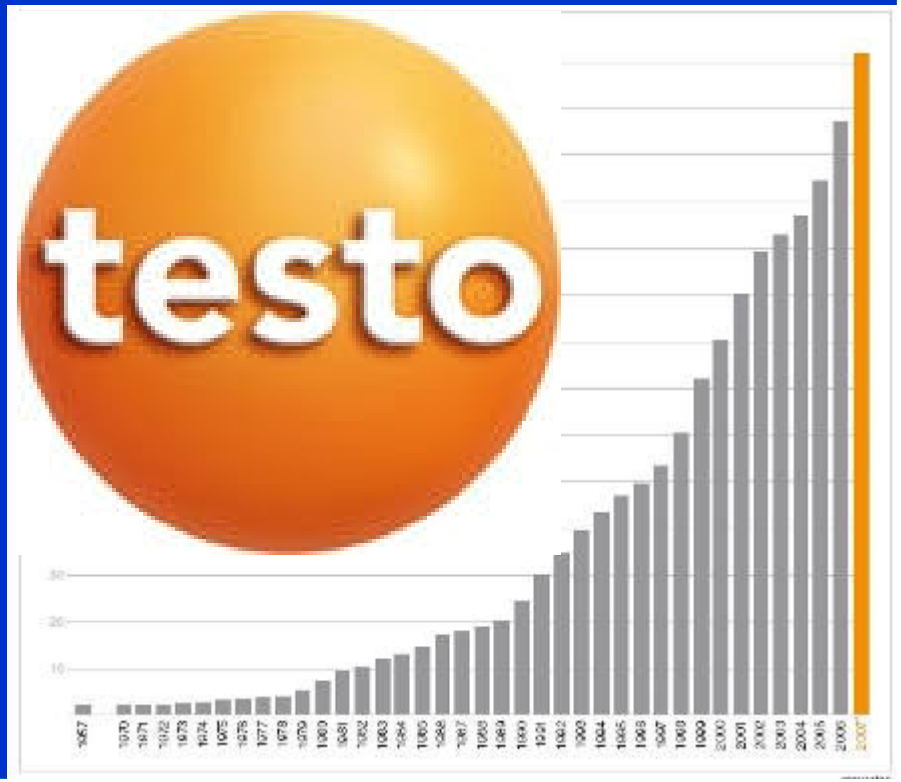


Measuring up

- Building performance evaluation Observation and measurements.
- Principles
- Practices
- Devices
  - Accurate
  - Powerful
  - Affordable

Bulk Assessment

- Thermal imaging
  - Detects thermal patterns
  - Non-uniform temperatures
  - Hot where it should be cold
  - Cold where is should be hot
- Used primarily as an investigative tool
- Proper training is essential

$5,000 + up

Thermal Imaging

- Insulation verification
- Locate air duct leakage
- Building performance
- Structural verification
- Moisture intrusion
- Problem solving

Important Features

- Lens system
  - High-quality, “wide-angle” (32°)
  - Telephoto option
- Close focus (4 inches)
- Detector array size (eg. 160 x 120 Pixels)
- Interpolated display (eg. 320 x 240)
- NETD < 0.1°C
- Ability to easily focus
- SD memory card storage
- Palettes
- Simple operating system
- Still and video software
- Report software
- USB connection
- Battery technology/performance (Li-ion)
- Carry case
- Digital camera/lighting system

Complete Analysis

- In addition to thermal imaging:
  - Relative Humidity
  - Material Moisture
  - Air Velocity
  - Air Leakage
  - Pressure zones
  - System performance
    - Heating
    - A/C
    - R-Value
  - Occupant Safety
  - Visual Observations

It's in the air

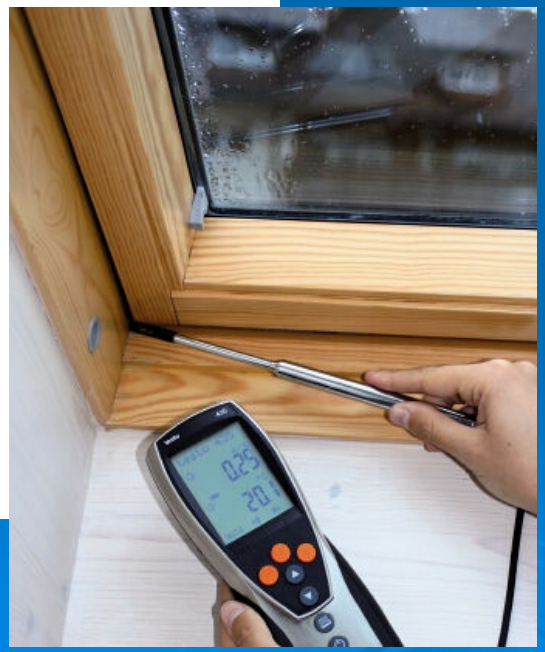
- Has mass
- Holds and releases thermal energy
  - N.A. Heat Transfer medium
- Holds and releases other ****
- Has a specific volume
- Is compressible
- Holds and carries moisture
- It's a gas!
  - Pressure induces migration

Measuring Airflow

- Standard air
  - 14.7 psia
  - 69 ºF
  - 0% rH
- Indirect measurement

  Density correction
- Velocity
- CFM
- Effect of turbulence

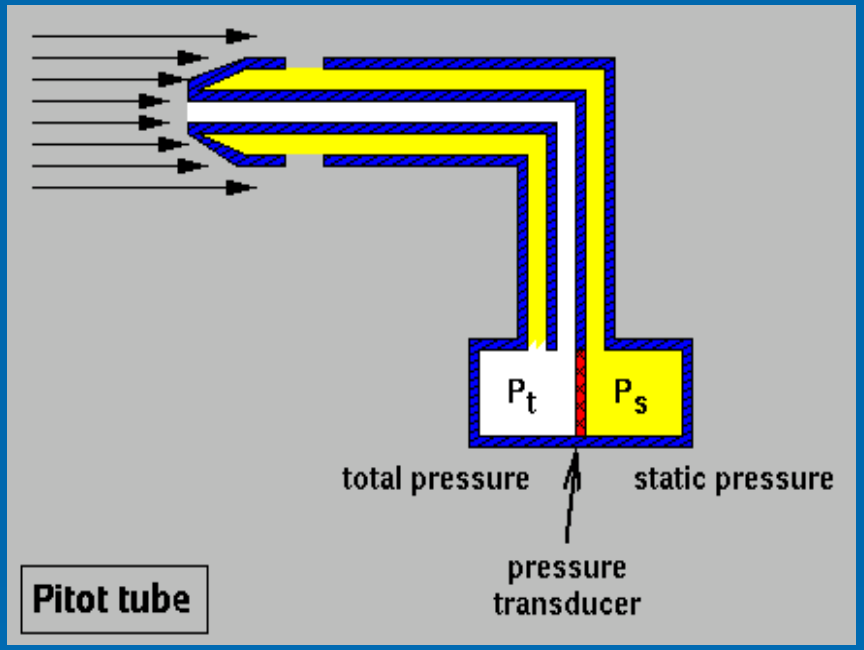
Thermal Anemometer



- Wind-chill factor
- Up to 2,000 fpm
- Up to 160 ºF
- Hot wire vs. hot ball
- Density correction
- Minute streamlines

$350 +

Pitot static / Pitot tube



- Kinetic energy to pressure
- Up to 20,000 fpm
- Up to 930 ºF
- Corrosive atmospheres
- Density correction
- Minute streamlines
- Alignment

Bernoulli's Equation: Measure difference in total and static pressure

static pressure + dynamic pressure = total pressure

$$\left(p_s + r \times \frac{V^2}{2} \right) = p_t$$

Solve for Velocity: $V^2 = \frac{2(p_t - p_s)}{r}$

$300 +

Rotating Vane Anemometer

$500

$600

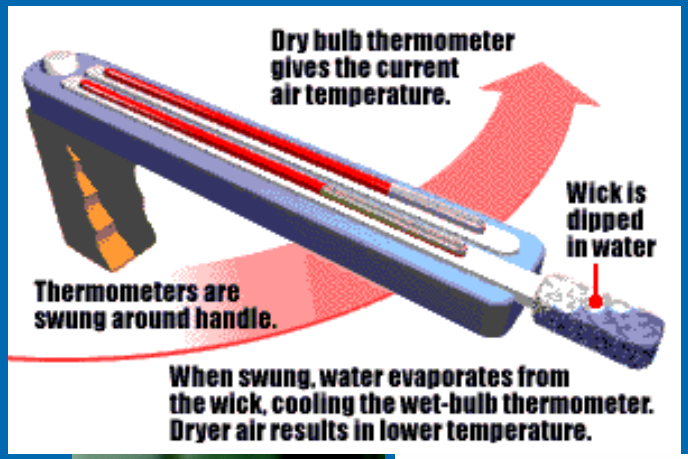
- A fan in reverse
- Large diameter (2.3” to 4”)
  - Turbulent flows
  - Up to 140 ºF
  - 4,000 fpm
  - Automatic CFM Calculation
    - Area + Grille Factor
- Small diameter (½”)
  - Turbulent flows
  - Up to 140 ºF
  - 8,000 fpm
  - Fits in a duct
  - Automatic CFM Calculation
    - Area
- Alignment
- Averaging
- No density correction!

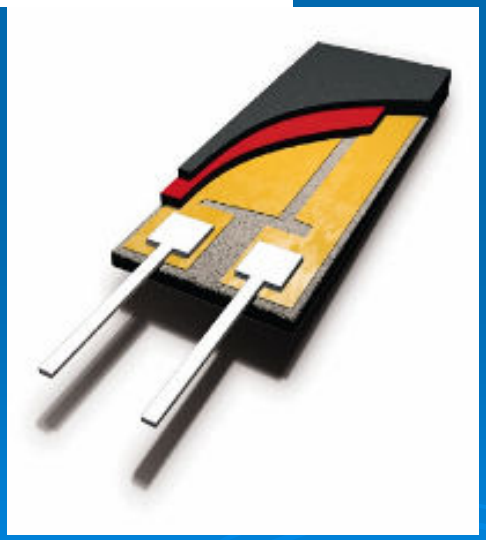
Infrared Temperature

$200 +

- Emissivity
  - Adjustable
- "Here Spot!"
  - Optics ratio
  - Average temperature
- Scan rate
  - You
  - The equipment
- Angularity
- Dewpoint distance
- Combined with contact measurement

Humidity





$100+

- Sling Psychrometer
  - Evaporative cooling
  - Cotton wick
  - Distilled water
  - Proper air-speed
- Dew point mirror
  - Visual condensation
- Capacitive sensor
  - Farad change
- Measurement technique
  - Response time
- Wireless

Some graphic: USA Today

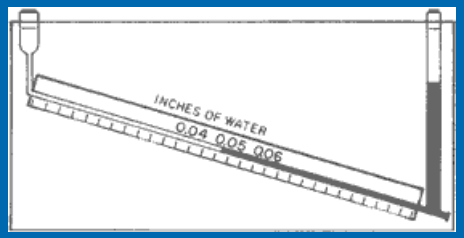
Material moisture

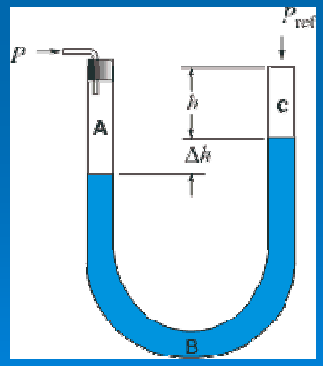
$200+

- Dry and weigh
- Scatter field
- Conductivity
- Contact
- Moisture ratio at equilibrium
- Microwave

Pressure

$$P = \frac{F}{A}$$





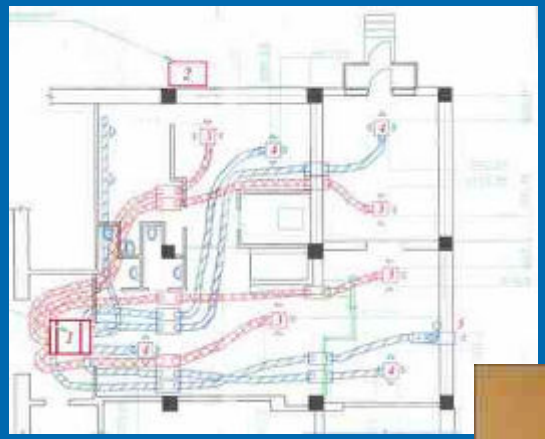
$150+

- Force per unit area
- Membrane displacement, gearing
- Water manometer
- Electronic sensors
- Differential
- Factors
  - Resolution
  - Hysteresis
  - Dead-band
  - Temperature
  - Orientation

Impact on Building Inspection

- Airflow leads to wind-chill
- Humidity as a source of moisture
- Moisture in materials
- Thermal damage
- The 4 “P”s
  - Pollutant
  - Pathway
  - Pressure
  - People

Building HVAC Systems



- Load Calculation
- Equipment Selection
- Equipment Installation
- Set up
- Performance
  - Comfort
  - Energy
- Diagnostics
- Safety

The Industry-recognized HVAC QI Specification

ACCA
AIR CONDITIONING CONTRACTORS OF AMERICA

2800 Shirlington Road
Suite 300
Arlington, VA 22206
703.575.4477
Fax 703.575.8107
www.acca.org

ACCA Standards are updated on a five-year cycle. The date following the standard number is the year of approval release by the ACCA-EI Standards Task Team. The latest copy may be purchased from the ACCA online store at www.acca.org or ordered from the ACCA bookstore via toll-free telephone at 888.290.2220.

ANSI
www.ansi.org

ACCA Standard

STANDARD NUMBER: ANSI/ACCA 5 QI–2007

HVAC Quality Installation Specification

Residential and Commercial Heating, Ventilating, and Air Conditioning (HVAC) Applications

The Air Conditioning Contractors of America Educational Institute (ACCA-EI) Standards Task Team (STT) develops standards as an American National Standards Institute (ANSI) accredited standards developer (ASD). ACCA develops voluntary standards as outlined in the ACCA Essential Requirements and the ANSI Essential Requirements. ACCA standards are developed by diverse groups of industry volunteers in a climate of openness, consensus building, and lack of dominance (e.g., committee/group/team balance). Essential requirements, standard activities and documentation can be found in the standards portion of the ACCA website at www.acca.org. Questions, suggestions, and proposed revisions to this standard can be addressed to the attention of the Standards Task Team, ACCA, 2800 Shirlington Road, Suite 300, Arlington, VA 22206.

www.acca.org/tech/qispec.pdf

Combustion Diagnostics

$900+

- Set-up
  - Draft, fuel pressure
- Efficiency
  - O2, temperature
  - Maximize CO2 …..?
- Safe Operation
  - Draft
  - Carbon Monoxide (CO)
- Proper measurements
  - Condense water
  - Particles
  - NO gas filter.. “false CO”
- Performance
  - BTU/hr

A/C System Performance

- Energy Conversion
- Enthalpy change
  - Wet-Bulb (humidity)
- Mass flow
  - Air CFM
- Performance
  - BTU/hr or Cooling Tons
- "Gauge free"

$800 - $1800

A/C System Set-Up

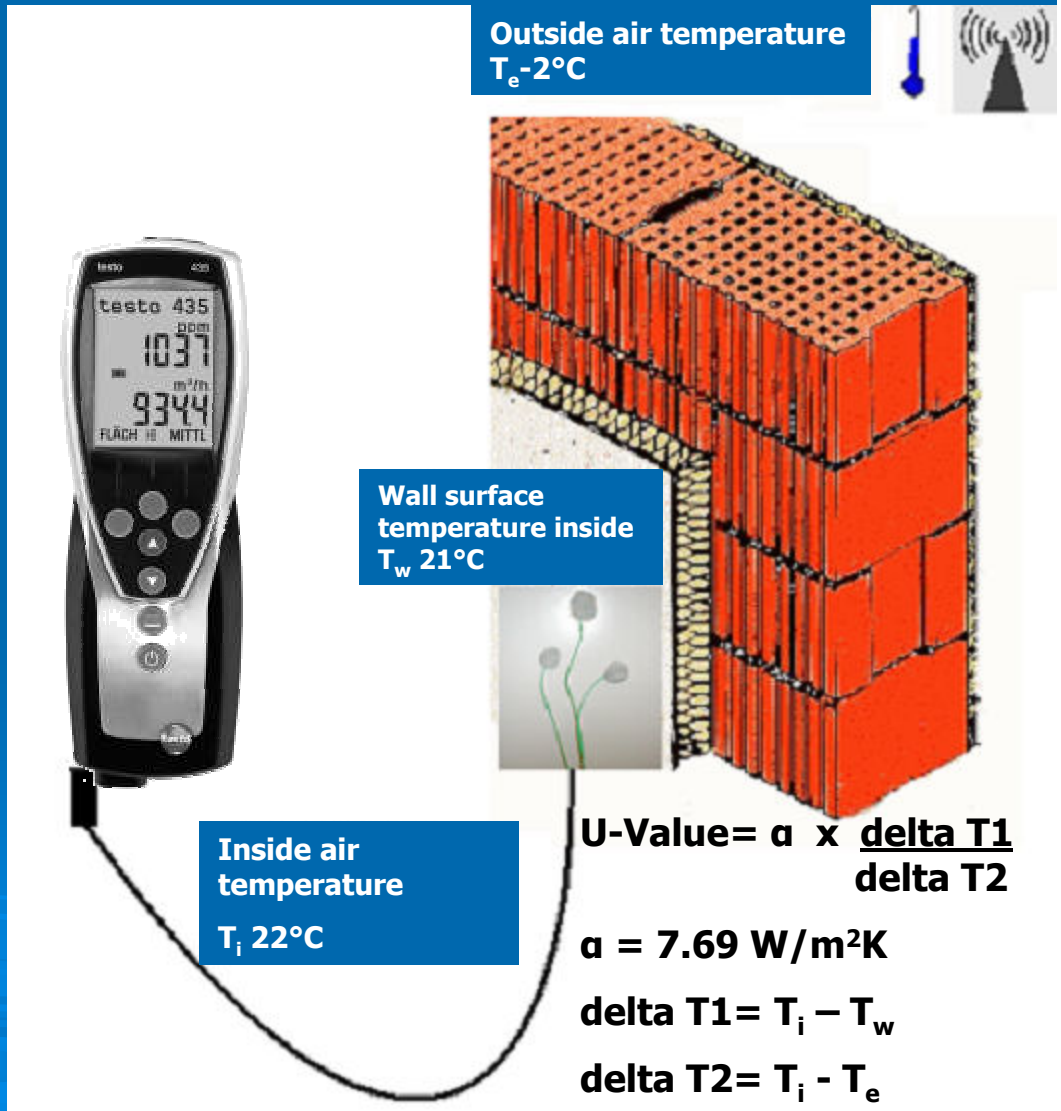
- Airflow
  - CFM
- Enthalpy change
  - Wet-Bulb (humidity)
- Refrigerant Charge
  - EPA 608 license
- Only as necessary!

$500 - $1500

U-Value / R-Value

- Need delta t of 15ºC (27ºF)
- Best if night time readings of 3 hours
- Convert to R-Value
- 1 K·m²/W ≈ 5.67446 ft²·°F·h/Btu

$1700



Safety

- Fuel gas leakage
- Refrigerant leakage
- Carbon Monoxide (CO)

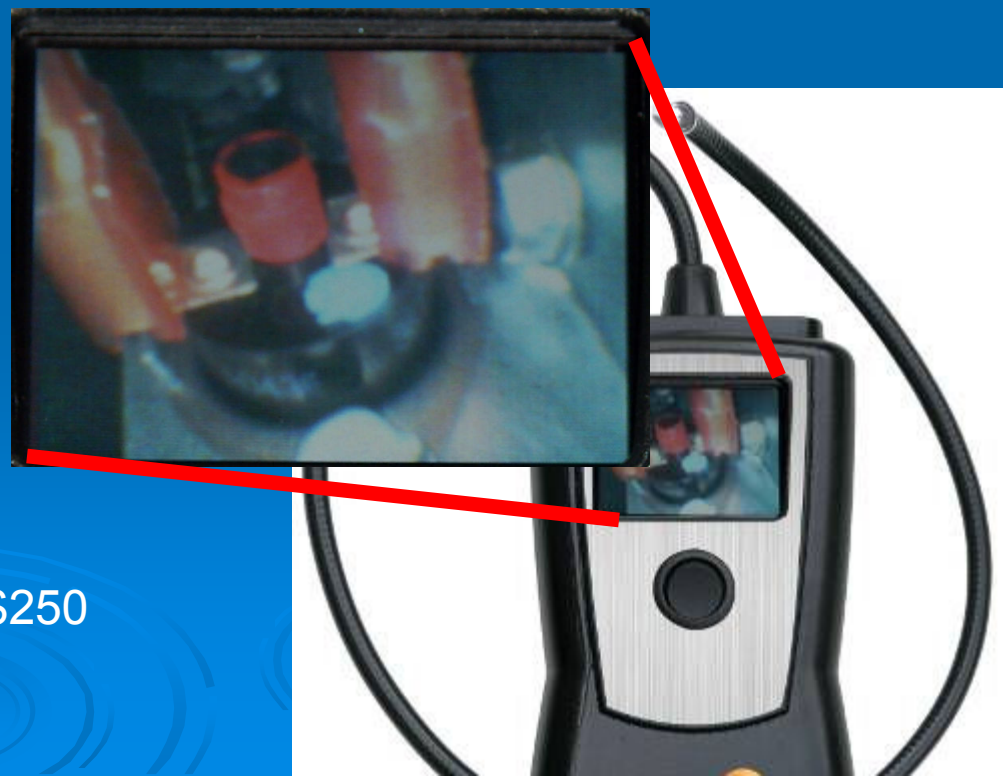
$250

$215

$450

Visual Inspection

- Human perception
  - Shared view
- Assessment of condition
- Access to equipment
- Clarity
- Durability
- Recording
- “Bubba says…”

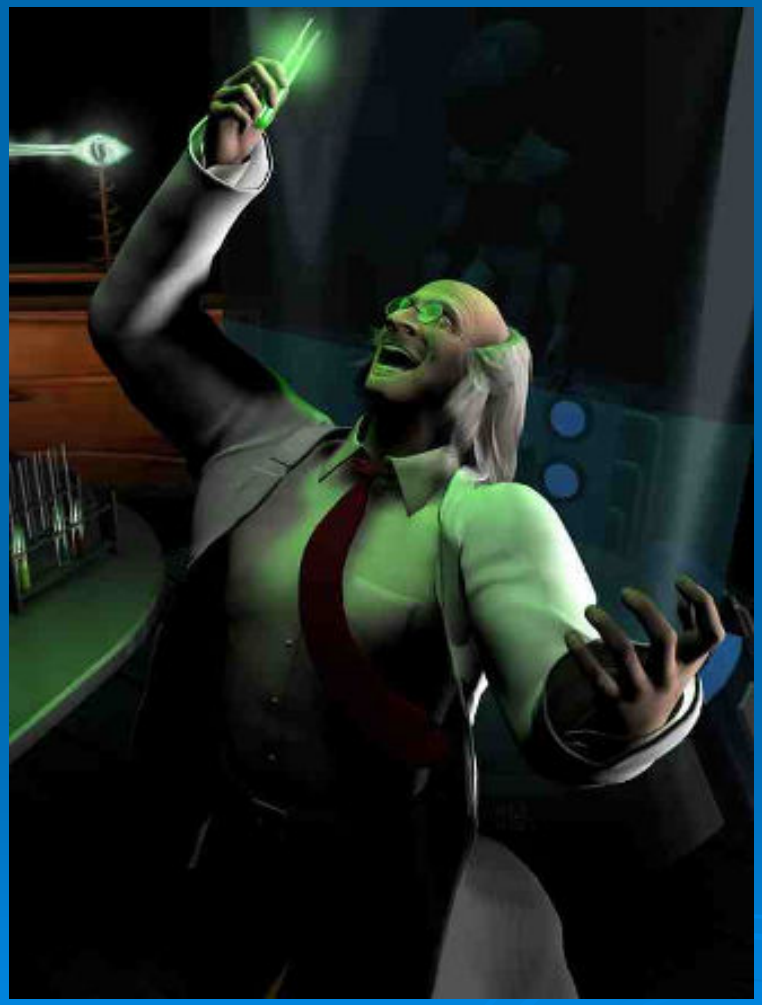


$250

In the words of Yul Brenner

- Et cetera
- Et cetera
- Et cetera
- DuctBlaster
- Blower Doors
- Et cetera

Good Measurements



- Defendable
- Repeatable
- Digital vs. “human”
  - Faster
  - Interpretation
  - “Tamper-resistant”
  - Easy documentation
  - Post-analysis
  - “Streaming data”

Image: Thermascan, UK