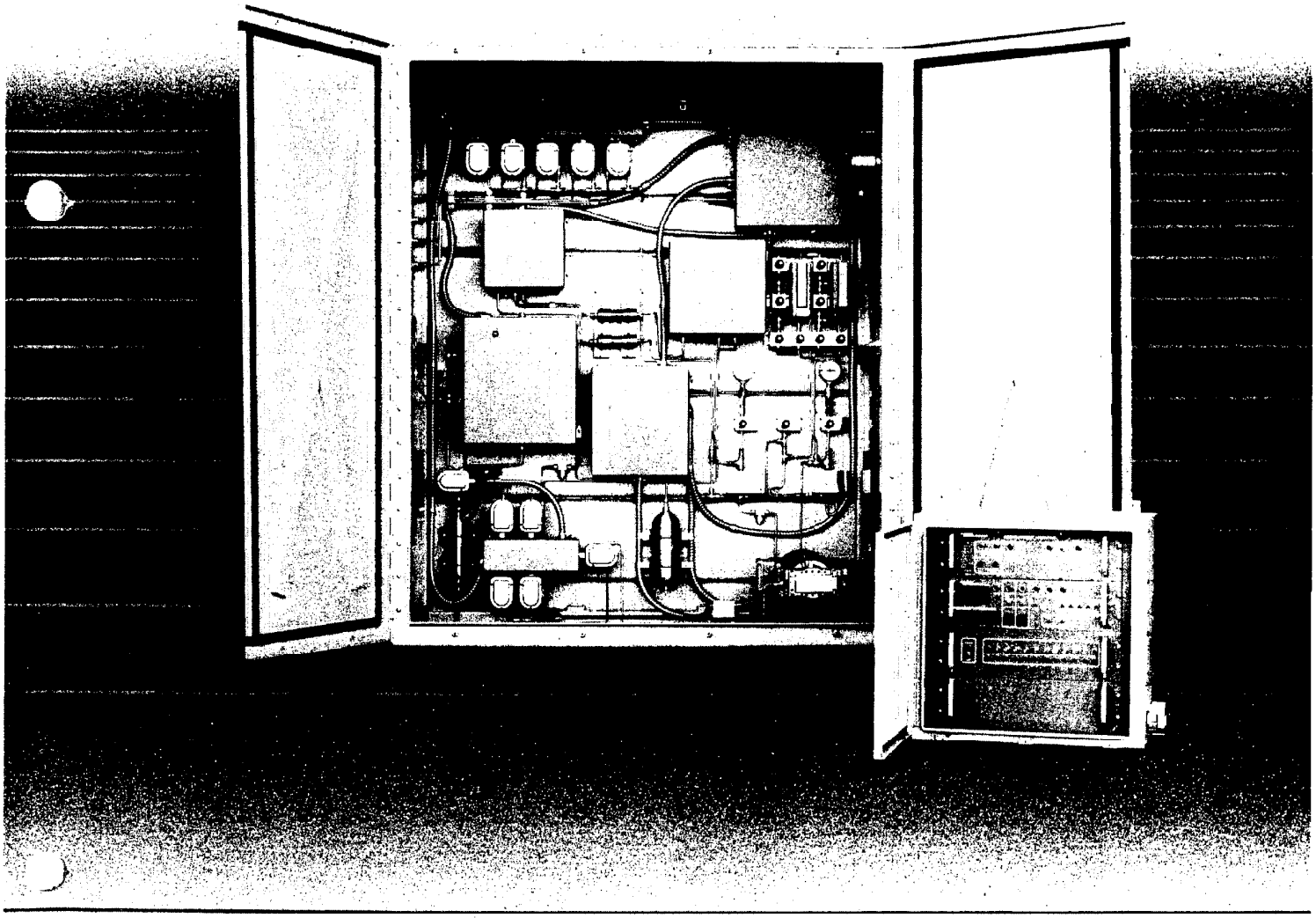
CONTAINMENT HYDROGEN MONITOR



TELEDYNE ANALYTICAL INSTRUMENTS

Containment Vessel Gas Sampling and Analysis Equipment

Table of Contents

SECTION I

Introduction:

Teledyne Products For The Nuclear Power Industry

For over 25 years, Teledyne Analytical Instruments has designed, manufactured, and marketed process analyzers and analyzer systems for a wide variety of monitoring and control applications.

In particular, for the nuclear power industry Teledyne specializes in safety-related equipment for **sampling and analyzing** gases from the containment atmosphere in post-accident situations. This equipment is intended specifically for use in nuclear power plants and is fully qualified for its intended service.

For further information describing Teledyne's products for the nuclear power industry, contact your local Teledyne Representative or contact us directly at: Teledyne Analytical Instruments, 16830 Chestnut Street, City of Industry, California, 91749, USA. Telephone (818) 961-9221, (213) 283-7181. TWX: 910-584-1887 TDYANYL COID, FAX: (818) 961-2538.

TELEDYNE
ANALYTICAL INSTRUMENTS

SENSORS • ANALYZERS • SYSTEMS
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SECTION II

The Containment Hydrogen/Oxygen Monitor

Teledyne's Series 225CM Hydrogen/Oxygen Monitoring Instrumentation provides on-line analysis of the atmosphere in the containment vessel following a loss-of-coolant-accident (LOCA) or steam line break (SLB). This analysis is important for helping determine the extent of reactor damage as well as the extent to which corrective measures should be utilized — such as activating hydrogen recombiners and purge systems — in a post-accident situation.

The Series 225CM is Class 1E safety-related equipment and is fully qualified to IEEE 323-1974 and IEEE 344-1975 (see Section VI for a complete list of relevant documents). The Series 225CM is designed and qualified to commence sampling operation coincident with a LOCA or SLB and continue functioning **without** maintenance for a minimum of 100 days. Continuous functioning for longer intervals, with or without accident conditions, is easily accomplished with a minimum of maintenance.

The Series 225CM is available as a hydrogen-only monitoring system — the Model 225CM — and as the more complete Model 225CMA system configuration that analyzes both hydrogen and oxygen. Several Analysis Unit/Control Unit configurations are available (see Figure 1) along with specific options to satisfy a wide variety of containment sampling and monitoring requirements.

System Description

The 225CM System consists of two major assemblies: The Analysis Unit and the Control Unit. The **Analysis Unit** (see Figure 2) — which is designed to be located in such areas as the auxillary building, fuel loading area, or annulus — contains the hydrogen/oxygen detectors and all sample system components necessary to extract and condition the sample prior to analysis. After analysis, all constituents of the sample are returned to containment.

The remote **Control Unit** (see Figure 3) can be located up to 500 feet (152 meters) from the Analysis Unit and contains all necessary electronics and controls to operate the System. The Control Unit includes the controls for the main system power, calibration, span and zero gas solenoid valves, and analytical range selection. Range of sample analysis is switch-selectable 0-10% to 0-30% H_2 by volume on a dry basis. Digital meter readouts of measurements are supplemented with 4-20 mA signal outputs, and a fully adjustable high alarm with free SPDT contacts is provided. An optional electronic digital Sequencer is available (see Section IV) for control of as many as twelve sample points.

	Model No.	Gases Monitored	Mounting Configuration For the Control Unit
1.	225CM	Hydrogen	All controls in a bulkhead mounted NEMA 4 enclosure.
2.	225CM-1	Hydrogen	Main control panel mounted in Control Room 19 inch relay rack. Other controls in a bulkhead mounted NEMA 4 enclosure.
3.	225CM-2	Hydrogen	All controls panel mounted in Control Room 19 inch relay rack.
4.	225CMA	Hydrogen and Oxygen	—Same as 225CM
5.	225CMA-1	Hydrogen and Oxygen	—Same as 225CM-1
6.	225CMA-2	Hydrogen and Oxygen	—Same as 225CM-2

Figure 1. Series 225CM configurations.

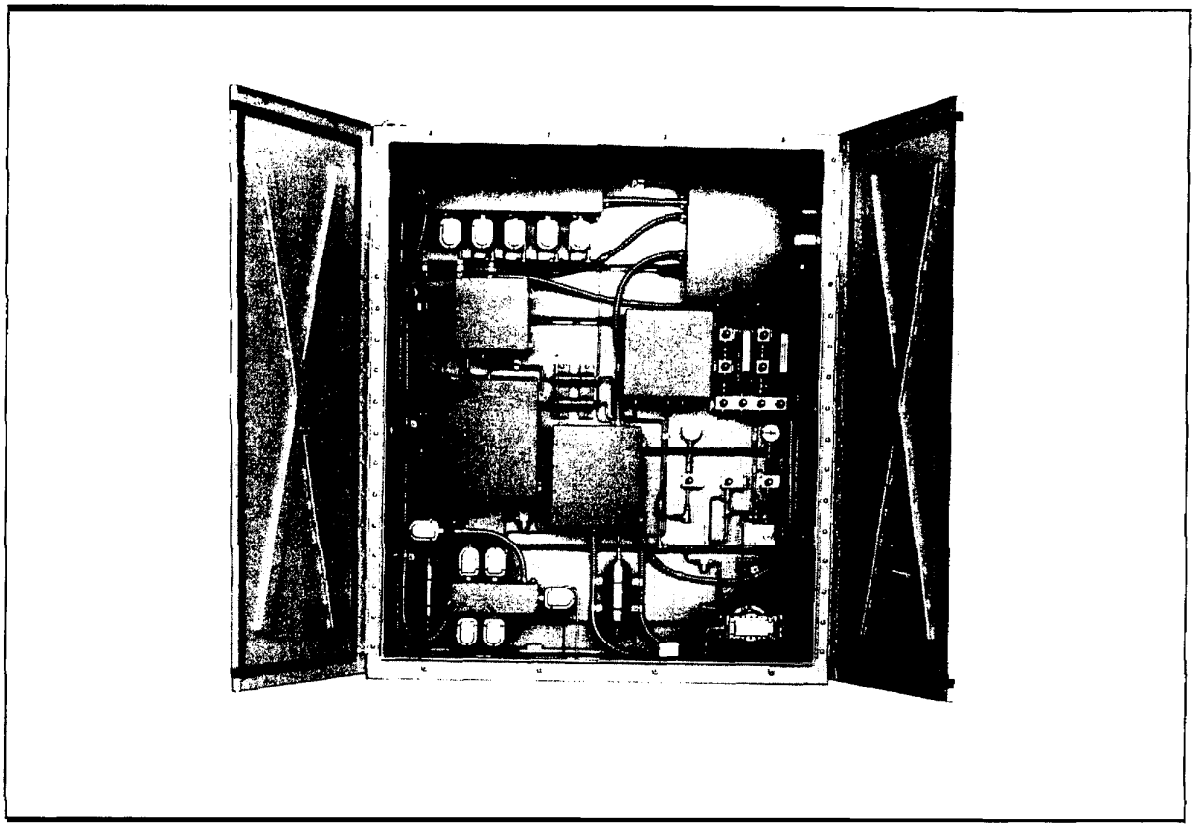

Figure 2. Analysis Unit

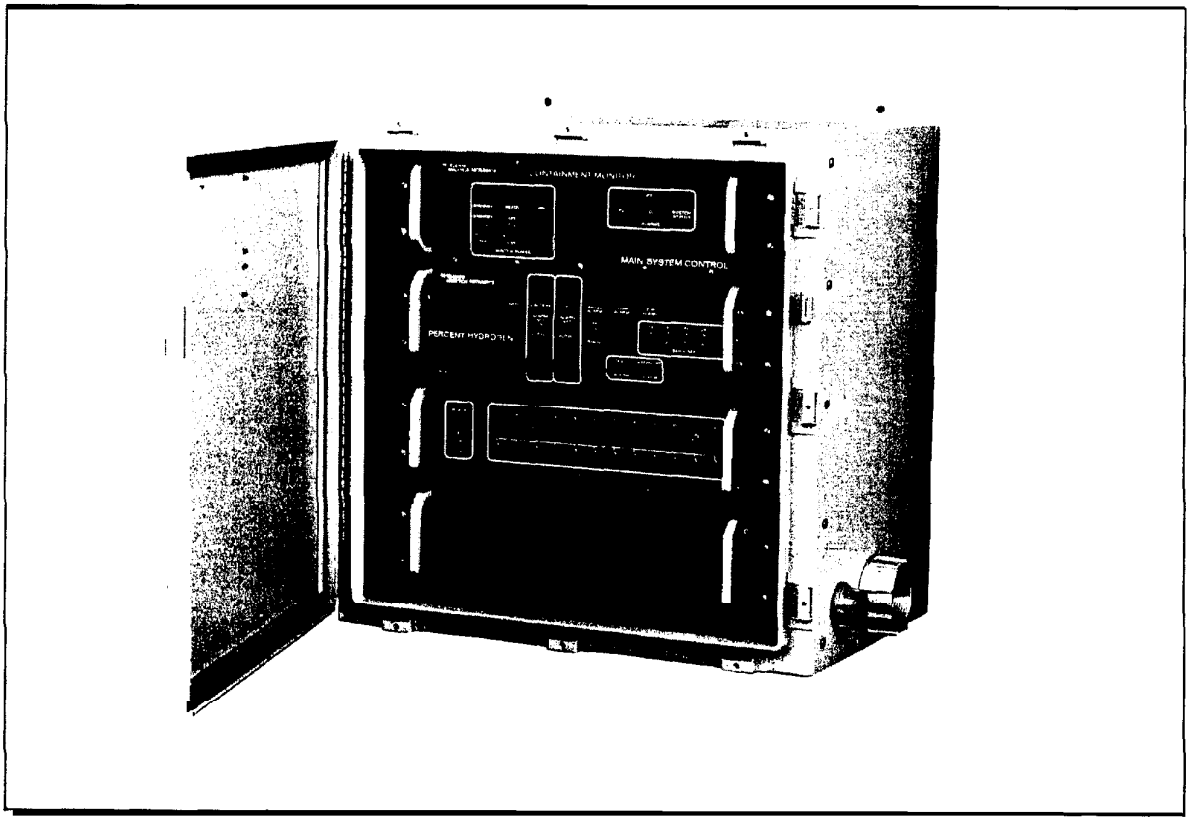

Figure 3. Control Unit

The 225CM Design

Inputs from major utility companies, engineering firms, regulatory agencies, and suppliers of nuclear power plant equipment — as well as Teledyne's own instrumentation and systems experts — contributed to the design philosophy behind the Series 225CM. In particular, the following key criteria were essential in the development of the Series 225CM.

General Qualification. The Series 225CM is Class 1E safety-related equipment that is fully qualified for its intended service in nuclear power plants. Included in this qualification is a test envelope, with margins (see Figures 4 and 5), stringent enough to satisfy most applications **and** expandable to satisfy more severe radiation, temperature, pressure, and seismic qualification envelopes. Note also that subsequent testing has expanded the qualification envelope (see Figures 6 and 7).

Reliable Operation. Parts of the Series 225CM, such as nuclear-qualified solenoid valves, the Thermal Conductivity detector (see Section II, "Principles of Detection"), and other critical components are selected specifically for this application to help assure reliable operation. Additionally, the whole 225CM was tested under accident conditions as detailed in the Test Procedures and Test Results. Plus, reliable operation is further assured by a comprehensive 18-point QA Program (see Section V).

Maximum Qualified Component Life. At normal ambient temperatures, most 225CM components have a qualified, real-world life of 40 years. This helps minimize your spare parts inventory as well as keeping maintenance costs as low as possible.

Minimum Maintenance Requirements. A simple calibration is the only required routine maintenance. (Replacement of certain components, such as valve seats, filter

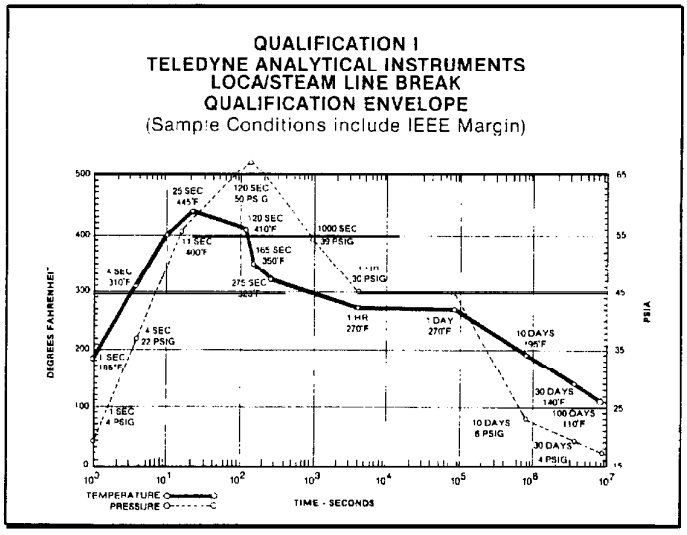

Figure 4.

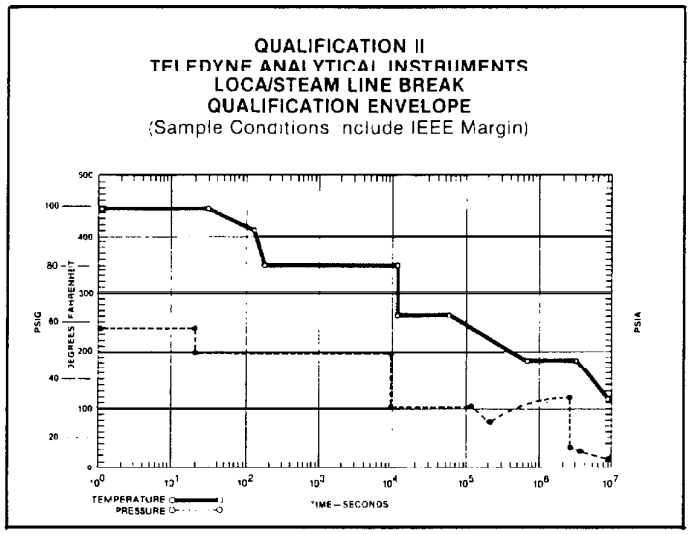

Figure 6.

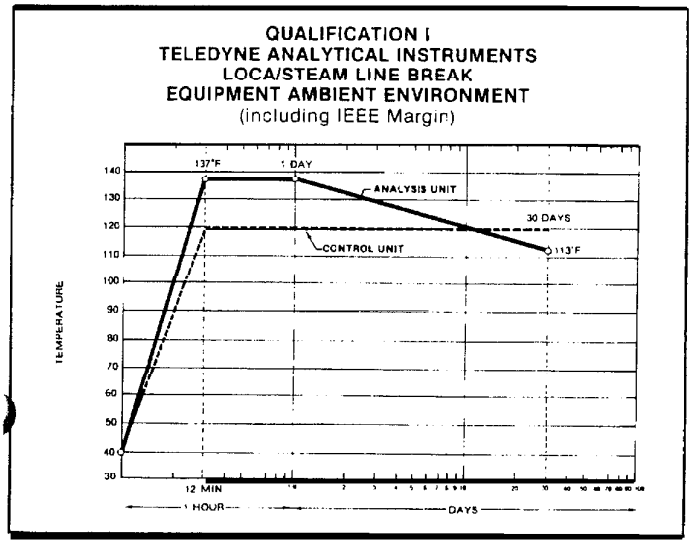

Figure 5.

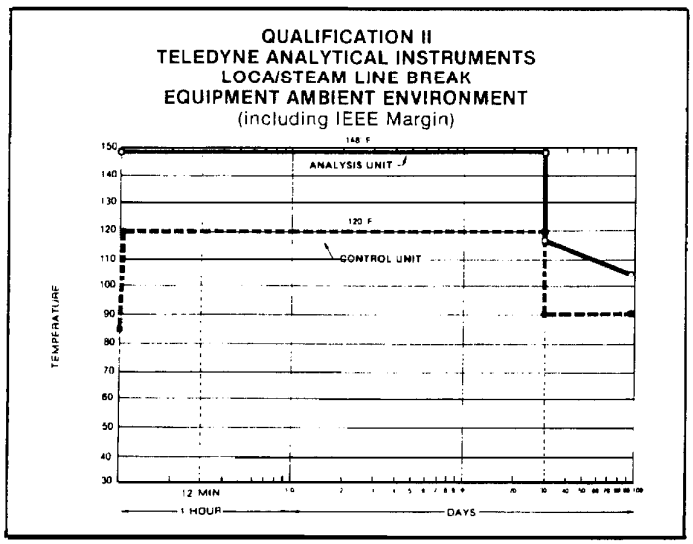

Figure 7.

elements, or pump diaphragms, may be recommended for certain applications, depending on expected service conditions. Contact TAI for maintenance recommendations for your particular application.)

Ease of Installation. The 225CM was designed for easy installation in existing nuclear facilities as well as for easy installation in new plants. Standard mounting configurations, electrical requirements, and other System features interface easily in most applications, and options are available (see Section III) to meet other installation requirements. For installation, the 225CM needs only one sample inlet line per monitor point and one line for returning the sample to containment. This single return line is sufficient for many multipoint sampling schemes, thus minimizing installation costs.

Also, the 225CM is ideal for replacing older, non-qualified equipment as well as for assuring that, once installed, you'll have the instrumentation you need for the life of your plant.

Minimize or Eliminate Support Facilities. Installation costs are further reduced by minimizing the need for certified gases. Since gases are only needed for calibration — not for routine operation — certified gas racks are not required. Also, for most applications, heat tracing of the sample lines is not necessary.

Easy Serviceability Under Adverse Conditions. The 225CM was designed to accommodate maintenance personnel dressed in protective clothing, so, should non-routine servicing ever be required, key service items and test points are easily accessible.

Sampling System

The 225CM utilizes a rugged pump-driven sampling system (see Figure 8) with several unique features that makes it ideal for reliable post-accident containment vessel gas sampling. The system includes a passive precooler mounted flat on a copper plate and bolted inside the Analysis Unit; this provides excellent sample heat dissipation, thus assuring that most condensibles in the sample will be removed.

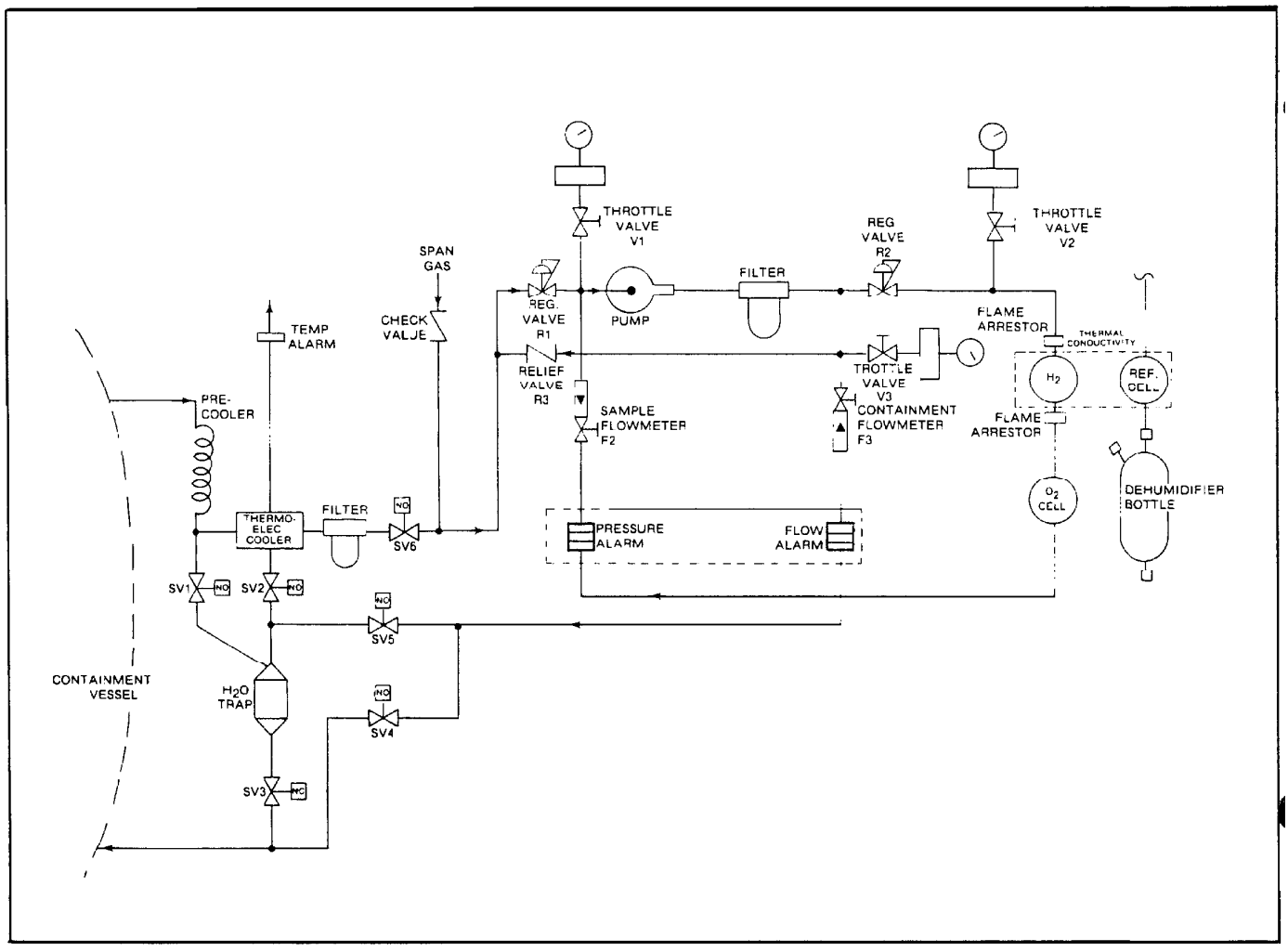

Figure 8. Sampling System

The sample is further cooled and dried using a thermoelectric cooler. This unique device is completely solid-state and has no moving parts, for high reliability along with effective performance.

The sampling system is a simple dual-loop pressure regulating network that has two important functions. First, the bypass loop is configured such that a positive differential pressure of 10 psi is constantly maintained between containment and the pump outlet, to assure proper ejection of all sample constituents back to containment. Also, this bypass loop allows the pump to "track" containment pressure changes and assure that the differential pressure is maintained at 10 psi. This has the added benefit of helping to maximize pump life.

The second function of the pressure regulating network is to allow proper control of the sample through the hydrogen/oxygen detectors.

Other features of the sampling system include: Sample pressure and flow alarms; a temperature alarm for the thermoelectric cooler; solenoid valves for control of span gases; and a special water trap that assures that all condensibles will be returned to containment with the gas samples. A special system is also available should an all-steam condition be anticipated.

WET VS. DRY MEASUREMENTS

Gas samples from the containment atmosphere following a LOCA or SLB are at elevated temperatures and humidity levels. The following two sampling approaches are both viable methods of analyzing the containment atmosphere.

- Maintain the gas sample above the dewpoint and and analyze the sample on a **wet basis.**
- Dry the sample by cooling it well below the dewpoint and analyze the sample on a **dry basis.**

The Series 225CM uses the dry-type approach because it offers a number of important advantages. Primary among these advantages is the fact that heating of the sampling system is **not** necessary because the cooled and dried sample always remains above the dewpoint. Not having to maintain the sample at 300-plus degrees F means that the temperature inside the Series 225CM cabinet is relatively cool (typically very near ambient), thus helping maximize the life of all Analysis Unit components. This dry-type approach also means that heating of the sample lines may not be necessary.

The main argument against dry basis measurements is that they are higher than wet basis measurements. A common misconception concerning this argument is that post-accident containment atmosphere samples are composed of almost nothing but moisture. Not so. In fact, the post-accident atmosphere during worst-case excursions to high humidity consists of at least 40% of air/hydrogen gases.

The dry measurement is higher than the wet measurement. However, this error is on the safe side, and it thus helps operators to react earlier to developing LOCA or SLB situations. Plus, as temperatures and humidity levels decrease — as inevitably happens following a LOCA or SLB — the difference between wet and dry measurements decreases.

Principle of Detection

After considerable investigation into different hydrogen detection principles, it was concluded that Teledyne's proven Thermal Conductivity (T/C) detector — with over 25 years of successful field operation in hundreds of process applications — was ideally suited for containment hydrogen monitoring.

T/C detectors are simple, rugged devices well-known for their reliable operation and long life. Combined with the fact that the 225CM T/C detector accurately and specifically monitors hydrogen in any conceiveable containment gas with little or no interference from gases such as xenon and krypton, it's easy to see why a T/C detector was selected to perform the hydrogen measurement.

The T/C detector in the 225CM (See figure 9) incorporates several features that are especially important for nuclear applications:

- Reference gases and reagent gases are not needed because the detector has a sealed air reference cell.
- The use of a sealed air reference cell also **eliminates the need for any catalysts** in the sample conditioning system. This also eliminates the problem of catalyst poisoning from the presence of certain contaminants in the containment atmosphere.
- Since support gases are only used for calibration and are not required for system operation, expensive, qualified, bottled gas racks and their associated plumbing are not required.
- Only a zero gas and a span gas are needed for periodic calibration. Five separate span gas inlets and solenoid control valves are included with the 225CM to allow checking the T/C detector calibration at several levels of hydrogen concentration and/or to allow extra on-line span gas capacity.

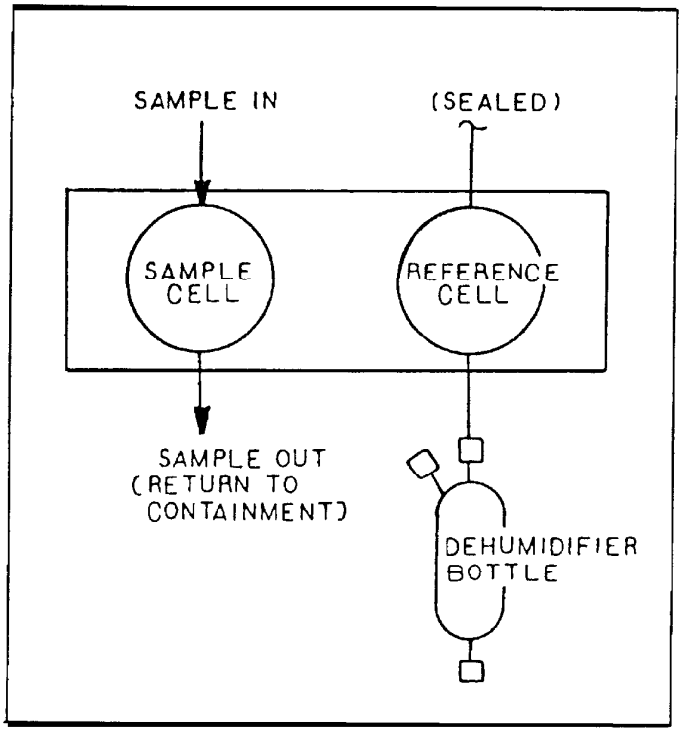

Figure 9.
Model 225CM
Thermal Conductivity Cell

QUALIFIED OPERATING SPECIFICATIONS

I. Design Criteria

1. Seismic I
2. Safety Class 1E
3. IEEE 323-1974, 344-1975
4. NUREG 0588
5. 10 CFR 50 APPENDIX B
6. Regulatory Guide 1.97, Rev. 2

II. Environmental Conditions, Normal (Non-Accident) Operation, 40 Years

1. Control Unit
   a. Ambient Temperature: 40-90° F (4.4-32° C)
   b. Pressure: Atmospheric
   c. Relative Humidity: 10-100%
   d. Radiation: 1.0 x 10^3 rads integrated 40 year dose (including accident)
2. Analysis Unit
   a. Ambient Temperature: 40-90° F (4.4-32° C)
   b. Pressure: Atmospheric
   c. Relative Humidity: 10-100%
   d. Radiation: 1.6 x 10^6 rads integrated 40 year dose (including accident). Wetted parts to 5 x 10^7 rads optional.

III. Environmental Conditions, Following An Accident

1. Control Unit
   a. Temperature: to 120° F (49° C). See Figures 5 and 7.
   b. Pressure: Atmospheric
   c. Relative Humidity: 10-100%
   d. Radiation: 1.0 x 10^3 rads integrated 40 year dose (including accident)
2. Analysis Unit
   a. Temperature: See Figure 5 and 7
   b. Pressure: Atmospheric
   c. Relative Humidity: 10-100%
   d. Radiation: 1.6 x 10^6 rads integrated 40 year dose (including accident). Wetted parts to 5 x 10^7 optional.

IV. Sample Condition Following An Accident

1. Temperature: to 430° F (221° C) See Figures 4 and 6.
2. Pressure: to 70 psia. See Figures 4 and 6.
3. Relative Humidity: See Figures 4 and 6.
4. Chemical Content: Water spray containing 1.3 weight/% boric acid and 0.52 weight/% sodium hydroxide.

V. Equipment Specifications

1. Accuracy: ± 2.5% of full scale (dry basis)
2. Stability: ± 2% of full scale (per month)
3. Response Time: 90% of reading in 120 seconds
4. Warmup Time: 30 minutes
5. Wetted Parts: Stainless steel and Viton (others available)
6. Zero Gas: Nitrogen
7. Span Gas:
   a. Thermal Conductivity Detector: Hydrogen in Nitrogen
   b. Electrochemical Oxygen Detector: Air

VI. Control Unit Specifications

1. Mounting: Bulkhead or 19 inch relay rack
2. Dimensions: Height: 25.2 inches (640 mm)
   Width: 24.0 inches (610 mm)
   Depth: 16.0 inches (406 mm)
3. Weight: Approximately 100 pounds (45 kilograms)
4. Utility Requirements: 115 VAC ± 10%, 60 Hz, 2A

VII. Analysis Unit Specifications

1. Mounting: Floor
2. Dimensions: Height: 72 inches (1829 mm)
   Width: 60 inches (1524 mm)
   Depth: 31.4 inches (798 mm)
3. Weight: Approximately 1150 pounds (523 kilograms)
4. Utility Requirements: 115 VAC ± 10%, 60 Hz, (100A, 460 VAC, 3-Phase, 60 Hz is available for the pump)

   Note: When the optional 460 VAC pump is ordered, utility requirements for the remainder of the system are 115 VAC, 60 Hz, 20A.

SECTION III

CHM Options

Oxygen Analysis (Inerted Containment)

Oxygen analysis and control of the containment atmosphere is provided with this option, which reduces costly and unnecessary inert purging. This oxygen *analysis can also assist with air purging of the* containment.

This option incorporates an oxygen detector that uses an electrochemical sensor for the accurate and specific measurement of oxygen. The use of electrochemical sensors has become virtually an industry standard for oxygen measurement; in particular, the 225CMA uses a special version of Teledyne's proven Micro-Fuel Cell* that is designed and contructed specifically for post-accident containment gas monitoring. The sensor has an absolute zero, so no zero gases are required. And because its output is linear with respect to oxygen concentration, air (20.9% 0_2) is an acceptable span gas.

The Oxygen Analyzer consists of 2 basic components: The Analysis Section and the Control Module. The **Analysis Section** is an integral part of the 225CMA Analysis Unit and includes the oxygen detector, sensor, stainless steel sample tubing, and other associated hardware needed to interface with the 225CMA System.

The **Control Module** includes the oxygen analyzer electronics, digital meter readout, alarm setpoints and relay contacts, switch-selectable dual range of 0-10/0-25% O_2 4-20 mADC output connections, indicator lights, and easily accessible fuse holders. The Module is designed for 19 inch relay rack mounting and can be included in the available NEMA 4 bulkhead mounted enclosure.

*Patent Nos. 3,429,796, and 3,767,552

Special Qualifications

Occasionally a nuclear power plant may have a certain requirement or specification, such as high ambient temperatures, that is outside the standard qualified specifications of the Series 225CM. In many cases it is quite possible to re-calculate certain qualification procedures or otherwise re-qualify the Series 225CM to meet **special qualification requirements.** Some examples of expanded qualified specifications include:

- Sample gas wetted parts qualified to 5 x 10^7 rads.
- System qualified for abnormal ambient temperature transients.
- Qualified life of system components at different ambient temperatures, under normal and/or accident conditions.

If one of your specifications or qualification requirements *is outside the standard Series 225CM specifications,* contact us and describe you needs. Chances are excellent that we can offer you a satisfactory solution.

3-Phase Motors

Not unexpectedly, initial electrical current requirements to start the Series 225CM are higher than under normal operation. This is especially true if the 225CM must start against a worst case containment pressure of about 50 psig. Under these conditions, the current draw to start the 225CM pump motor is 3 times that of the remainder of the 225CM Analysis Unit.

For that reason, Teledyne offers an optional 460 VAC, 60 Hz, 3-phase pump motor that is powered separately from the Analysis Unit. This reduces the current requirements for the remainder of the Analysis Unit to just 20A (@ 115 VAC, 60 Hz).

50 Hz motors are also available upon request for certain applications.

SECTION IV

Electronic Sequencer/Controller Module

To complement the Series 225CM Containment Hydrogen Monitor, for multipoint sampling Teledyne offers an **Electronic Sequencer/Controller Module** (see figure 10). The Module provides 12 sets of SPDT relay contacts, sequenced and controlled by an integral electronic timer, for selection and control of from 1 to 12 separate points. The Module is provided **fully qualified** to meet the same standards as the Series 225CM Control Unit.

The Sequencer/Controller Module features a digital timer design with all solid-state electronics, providing precise and rapid electronic control. The module also features a stepped 4-20 mADC position identification signal, clearly visible position indicator lights, toggle switches for manually or automatically omitting any of the 12 positions, and a manual override mode for instantaneous selection of any individual position. Dwell timing for each position is easily field-adjustable from 1 to 255 minutes.

Operation

The module operates sequentially to change the state of each of the 12 position's SPDT relay contacts, one after the other. For example, when position No. 1 is selected, all other 11 positions are not selected. And, position No. 1 remains selected for the period of dwell time set by the operator. At the end of that time period, position No. 2 is then automatically selected for the same dwell time. And so on throughout the 12 positions. The identification signals and relay contacts for each of the 12 positions are easily and conveniently accessible from screw-type terminal blocks located safely on the inner back panel of the module.

Any position(s) can be deleted from the automatic sequencing by use of the manual omit switches. Also, any signal position can be manually selected (over-ride mode) by activating the manual "OMIT" toggle switches for all the other positions. An indicator light above each OMIT switch is activated when its position is selected.

Specifications

Dimensions:	5 x 13 x 19 inches (height x depth x width) (127 x 330 x 483 mm).
Configuration:	For mounting in 19 inch relay rack (standard). Bulkhead mounted version is available (optional)
Number of positions:	1 to 12
Time per position:	1 to 255 minutes
Power Requirements:	115 VAC ± 10%, 50/60 Hz
Radiation Tolerance:	10^3 rads
Operating Temperature Range:	32 - 135° F (0-57.2°C)
Humidity:	98% R.H.
Qualified Life:	40 years at 90° F (storage) operation limited by relay cycle life
Relay Cycle Life:	10^5 operations at full load (equivalent to 34 years of continuous operation at all 12 points at 15 minutes/point) 10^7 operations at no load
Relay Contacts:	3A 120 VAC or 30VDC, SPDT resistive

Options

- Valve Status Indicator Module. This option confirms the ON/OFF status of solenoid valves controlled by the sequencer. Mounting is 19 inch relay rack or optional NEMA 4 bulkhead mounted enclosure.
- Special versions of the sequencer are available to satisfy unique application requirements (e.g., auxillary position indicator lights, isolation valve control switches, special identification output signals, and others). Contact Teledyne if you have a special requirement.

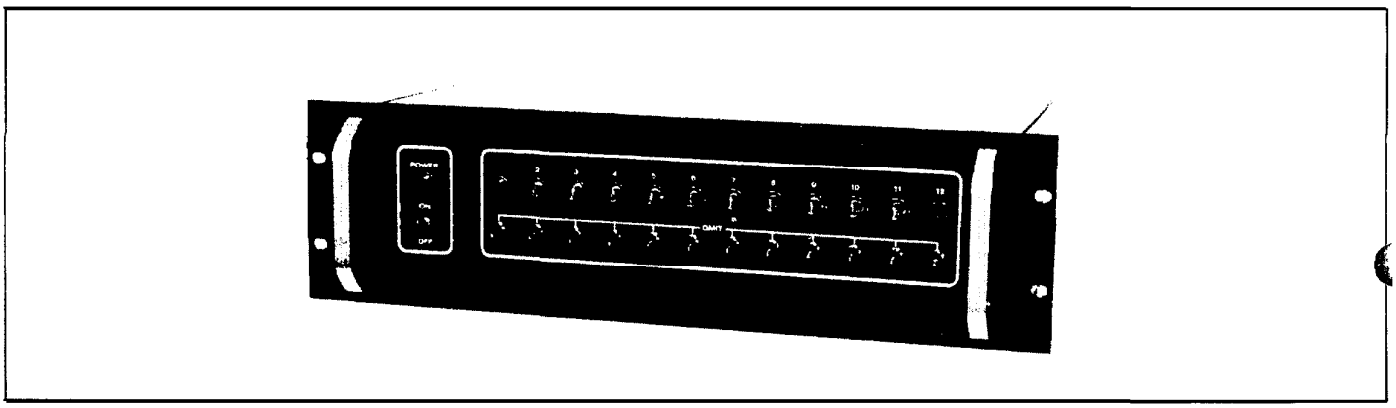

Figure 10. Optional Sequence/Controller Module

SECTION V

The Quality Assurance Program

As a supplier of Class 1E safety-related containment atmosphere monitors, Teledyne has a complete 18-point Quality Assurance (QA) Program that meets applicable nuclear power plant standards (see Section VI). This QA Program is **more** than just a means to meet standards; it is our way of concretely demonstrating our commitment to providing top quality equipment, on-time delivery, and no surprises. This helps you in the following ways:

- QA surveillance and verification of compliance can save money. Any unscheduled down-time, due to equipment delays or failure, that is prevented by QA is a time/cost savings.
- QA enhances reliability. By surveillance of suppliers, QA may spot and correct a potential failure.
- The QA Program parallels the equipment construction program and acts to assure that the quality delineated in the design documents is preserved and achieved in the end product.

Scope of the QA Program

The QA Program includes, but is not necessarily limited to, the following 18 points:

1. Quality Assurance Organization
2. Quality Assurance Program
3. Design Control
4. Procurement Document Control
5. Instructions, Procedures, and Drawings
6. Document Control
7. Control of Purchased Material, Equipment and and Services
8. Identification and Control of Materials, Parts, and Components
9. Control of Special Processes
10. Inspection
11. Control of Tests
12. Control of Measurement Equipment
13. Handling, Storage, and Shipping
14. Inspection, Test, and Operating Status
15. Control of Nonconformance
16. Corrective Action
17. Quality Assurance Records
18. Audit

These 18 points are described in the Teledyne Quality Assurance Manual. Also, these points are evident in the form of **formal procedures** as well as in actual, audited practices. Copies of specific procedures are available upon request.

SECTION VI

Applicable Codes, Standards, and Other Reference Documents

I. Source: Teledyne Analytical Instruments (TAI)
   A. **Qualification Plan.** Final qualification of TAI Containment Monitor System performed by Wyle Laboratories. Rev. D, May 21, 1981.
   B. **Test Results.** Report on qualification on TAI Containment Monitor System. Rev. B, September 22, 1982.
   C. **Quality Assurance Manual.** 18 point QA Program.

II. Source: U.S. Nuclear Regulatory Commission (NCR)
   A. **Regulatory Guide 1.97 Rev. 2.** Instrumentation for Light-Water Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following An Accident.
   B. **10 CFR Part 50 APPENDIX B.** Quality Assurance Criteria for Nuclear Power Plants and Fuel Re-Processing Plants.
   C. **NUREG - 0588.** Interim Staff Position on Environmental Qualification of Safety-Related Electrical Equipment.

III. Source: Institute of Electrical and Electronic Engineers (IEEE)
   A. **IEEE 323 - 1974.** Standard for Qualifying for Class 1 Electrical Equipment.
   B. **IEEE 344 - 1975.** Recommended Practices for Seismic Qualification of Class 1 Electrical Equipment.
   C. **IEEE 308.** Standard Criteria for Class 1E Systems for Nuclear Power Generating Stations.

IV. Source: American Society for Testing and Materials (ASTM)
   A. **A - 182.** Forged Fittings.
   B. **A - 269.** Seamless Austenitic Stainless Steel Tubing for General Service.
   C. **A - 276.** Stainless and Heat-Resisting Steel Bars and Shapes.
   D. **A - 380.** Cleaning and Descaling Stainless Steel Parts, Equipment and Systems.

V. Source: American National Standards Institute (ANSI)
   A. **ANSI/NFPA 70.** Electrical Code.
   B. **B31.1.** Power Piping Code.
   C. **N45.2 - 1977.** Quality Assurance Program Requirements for Nuclear Facilities.
   D. **N45.2.2 thru N45.2.23.** Daughter Standards; As Applicable.

VI. Source: American Society for Nondestructive Testing - June, 1975, SNT-TC-1A
   A. **SNT-TC-1A.** Recommended Practice for Non-destructive Testing Personnel Qualification and Certification.

VII. Source: Steel Structures Painting Council - 1964
   A. **SP - 1.** Solvent Cleaning.
   B. **SP - 10.** Near White Blast Cleaning.

VIII. Source: American Welding Society.
   A. **AWS D1.1 1982.** Welding Specification.

IX. Source: TAI Quality Assurance Procedures.

Specifications/Features: vary with application; are established and validated during design; are not to be construed as test criteria for every product manufactured; and subject to change without notice.