# Emerging ASME AG-1 Code: Article FI, On Metal Medium Filters.

Lawrence D. Weber, Ph.D.
Savant/E-C Instrument Co.
Subsidiary of ThermoQuest™ Corp.
100 Colin Drive
Holbrook, NY 11741-4306

## Abstract

Metallic filters may withstand high levels of moisture, temperature, and pressure differentials/ transients. They may also be cleaned for re-use under properly prescribed procedures.

To ensure responsible deployment of this technology, ASME has undertaken to develop a Code regulating metallic filters under the umbrella of the ASME AG-1 Code on Nuclear Air Treatment and Gas Processing. The section is designated Article FI, and is commissioned with the following scope statement:

"This section of the Code provides requirements for the performance, design, construction, acceptance testing, and quality assurance of metal medium filters used in nuclear safety related air and gas treatment systems."

Article FI has been evaluated, and reached the stage of acceptance ballot by the Subcommittee on Ventilation Air Cleaning Equipment.

Highlights of the testing, design, performance and qualification requirements of Article FI are presented. Some practical geometric and system considerations for deployment of metal filter technology as a genre are outlined.

## Introduction

HEPA filters have protected the public safety in nuclear applications for half a century. Supporting this function are recognized government and consensus Codes and Standards designed to maintain defined performance characteristics and reliability of filters shipped to users and also, in effect, provide users' oversight of like products in development.

The TMI event (1979) and the Chernobyl accident (1986) spurred development of all metal filters for reactor containment pressure relief.[1,2,3] A technologic prompt was the availability of stainless steel fibers, which could be used to prepare metal filter medium with lower resistance to airflow at a given filter efficiency than commercial sintered powder technology.

Filters of all stainless steel are attractive in some applications due to their strength, durability, moisture resistance, temperature resistance, potential for cleaning and re-use (occupational exposure and radwaste volume reduction) and, in some cases, their chemical properties.

Metallic filters have now been employed in France, Germany and other European countries in containment venting, and have been further examined extensively on behalf of a variety of applications in the U.S., including those calling for low pressure drop and for efficiency of ≥99.97% or better at most penetrating particle using dioctyl phthalate smoke. [4,5,6,7,8,9,10,11]

Applications in the U.S. have involved principally those associated with the Department of Energy and its site cleanup program (tank ventilation, waste vitrification, ablation processes, and others).

Recognizing the increased field application of metal filters, progress in the technology, and expanding nuclear markets (particularly in Asia), the ASME has responded by developing a new draft "Article FI, Metal Medium Filters" for the AG-1 Code. On behalf of the Subcommittee on Ventilation and Air Cleaning Equipment and of the Article FI Subgroup, highlights of the emerging CodeArticle FI are herein presented.

## What Is A Hema Filter?

Simply put, a HEMA filter is a high efficiency metal air filter of metal filter medium, with rigid hardware. (Note: the name HEMA, although superficially analogous to a well known acronym, is not itself a direct acronym.)

## Hema Filter Performance.

### Efficiency

The filter shall exhibit a minimum efficiency of 99.97% at most penetrating particle diameter, or as measured by penetrometer, when tested with an aerosol of essentially monodispersed 0.3 micrometer test aerosol particles.

Test aerosol is defined as a dispersion of particles in air containing 80 ±20 micrograms per liter of particles 0.2 to 0.3 micrometers dia. at $\sigma_g$<1.3.

### Pressure Drop

At rated flow, clean pressure drop shall be no greater than 2.5" w.c. (625Pa). At terminal pressure drop in service, the HEMA filter is either cleaned for re-use or decommissioned. Article FI calls out qualification testing for HEMA filters intended to be cleaned and re-used, but the decision to prepare a given unit for another service cycle is outside its scope.

## HEMA Filter Construction

Article FI calls out three Types of construction:

Type A. All metal. (May be brazed.) Rated to 750degF (399degC) continuous, air.

Type B. All metal welded. Rated to 750degF (399degC) continuous, air.
Type C. Metal medium seal to hardware by potting.
C-1. Urethane potting rated to 250degF (121degC) continuous, air.
C-2. Epoxy potting rated to 350degF (177degC) continuous, air.
C-3. Silicone potting rated to 550degF (288degC) continuous air.

Design
Geometry is not restricted. Design spans cylindrical modules to panels, for example as illustrated in Figures 1, 2, and 3. Where panel geometry is used, sizes shall be according to Table 1.

## Acceptance Criteria

The acceptance criteria are: no structural damage shall be evident by visual examination; and airflow resistance and aerosol penetration requirements of the Qualification Testing (below) shall be met.

## Qualification Testing of New or Revised Hema Filter Designs

New or revised filter designs shall require qualification testing prior to acceptance and production.

Testing shall be performed at UL, ETL (Inchcape Testing Services), government, or other certifiably qualified, independent facilities; or at a manufacturer's facility under similarly qualified and independent oversight. A summary Report will be prepared by the independent agent certifying qualification to Article FI of this Code.

A qualification sample of 2 of each size HEMA module or panel shall be manufactured using the same methods, materials, equipment, and processes as will be used during production. The test sequence is detailed in Table 2.

The 2 filters used in the qualification sample shall be run sequentially through the tests in the order given in Table 2. (A total of 2 filters shall be tested). Failure of any filter to comply with the requirements of this section shall be cause for the rejection of the qualification sample.

The types of tests called out in the sequences of Table 2 are briefly called out as follows.

### Resistance To Airflow

The clean filter resistance to airflow shall be 2.5inches water gauge or less.

### Test Aerosol Penetration

The total test aerosol penetration through the filter media, case, and gasket shall be no greater than 0.03% of upstream concentration of test aerosol at rated airflow and at 20% of rated airflow.

Resistance To Rough Handling

Modules and assembled panels shall be tested on a rough handling machine for 15 min. at 0.75 in. (19 mm) total amplitude at 200 cycles per min. The filter shall be placed on the machine with the pleats (if any) in a vertical orientation. At the conclusion of the shaking period, the filter shall be visually examined for damage.

Resistance To Pressure

Filters (modules or panels) shall be subjected to a flow sufficient to produce the maximum rated pressure differential at the rated maximum temperature. This shall be sustained for a period of 1 hour, minimum. To achieve maximum differential pressure, a contaminant may be added to the airstream in order to increase resistance.

If the filter is intended to be cleaned for re-use during its service life, then it shall be cleaned prior to subsequent testing.

Resistance To Heated Air

For resistance to heated air, the filter (module or panel) shall be subjected to the rated flow of air heated to the rated maximum temperature ±50Fdeg for no less than 30 min. For panels, the face of the gasket and outer sides of the filter case need not be exposed to heated air. An Underwriters' Laboratories label (UL-586) shall be acceptable objective evidence of compliance with this test.

Spot Flame Resistance

The basic procedure is identical to that described in AG-1 Article FC, and is applied to FI Type C devices (which employ designated potting materials). An Underwriters' Laboratories (UL-586) label shall be acceptable objective evidence of compliance.

Radiation Resistance

For this stage of testing, the filter assembly shall be subjected to a minimum total integrated dose of $8 \times 10^7$ rads (gamma) at a dose rate not to exceed $2.0 \times 10^5$ rads/hr (gamma).

## Production Testing

Each HEMA filter manufactured for delivery shall be tested for test aerosol penetration and resistance to airflow, unless alternative test methods are agreed to by owner or engineer.

## Cyclic Fatigue Testing Of Cleanable Assembly Designs

A notable operating feature of HEMA technology is its cleanability. Not all HEMA filter/assembly designs will be manufactured for repeated cleaning cycles, but those which are shall be qualified by a procedure summarized as follows.

1. The filter shall be subjected to an initial aerosol penetration test.
2. The filter (either clean or laden with a contaminant) shall then be exposed at maximum rated continuous temperature to sufficient airflow to generate maximum rated pressure drop.
3. The filter so exposed shall be subject to complete cleaning (with flushing and drying as applicable) by the procedure specified by the manufacturer, or as agreed to by the manufacturer and owner or engineer. Recovery differential shall be measured at rated flow.
4. Steps 2 and 3 shall be repeated cyclically as applicable. Where a high number of rated cycles makes this impractical, pressure pulsation fatigue testing with the filter submerged in the cleaning fluid may be substituted.
5. A repeat aerosol penetration test successfully passed shall conclude this sequence.

Filter cleanability is often a function of the contaminant type and proper selection of cleaning conditions. This qualification section is designed to assure the user of a filter that can physically withstand the cleaning procedure specified by agreement between vendor and owner or engineer, or withstand a generic one so specified to physically qualify a filter. (The design must simultaneously meet the Qualification Testing requirements, outlined above.)

## Manufacture And Assembly

ASME AG-1 Articles AA-6200 and AA-6300 shall apply.

## Filter Media

The filter media or medium for a given construction may be supplied either flat or as unfinished seamless tubes. In the case of sheet media supplied for panel construction by direct attachment to the panel case, one dimension shall meet or exceed that of the case.

### Splices

All metal bonding techniques shall be used in splices, for Types A and B and C devices.
For Type C devices, splices may also be made by sealing employing adhesives exhibiting the same applicability as the potting compound.

### Tensile Strength

The influence of tensile strength or elongation properties on a finished HEMA filter is governed by its construction. Media successfully used to qualify filter designs in accordance with relevant sections of FI will be deemed qualified on tensile strength.

## Conclusions

The following apply to ASME draft Article FI.

1. It is non-restrictive with respect to filter geometry and metal medium manufacturing method, provided the performance and qualification requirements are met.

2. It requires the entire set of applicable qualification tests to be carried out sequentially using the same filters.
3. It requires structural qualification to demonstrate a filter design can withstand its cleaning procedures to the maximum rated cycles, after cyclic exposure to maximum rated pressure drop and temperature.
4. It requires a maximum clean pressure drop of 2.5" w.c., reflecting the life expectancy, cleanability, and in some cases high area of metal filters.
5. It requires filter efficiency of 99.97% at most penetrating particle diameter, or as measured by penetrometer.
6. The test aerosol may be DOP or any other material meeting the test aerosol definition.

In summary, it is respectfully submitted that the draft Code provides rigor on behalf of protecting the public and the end user, while also allowing manufacturers significant flexibility provided the performance and qualification requirements are met.

Acknowledgement

The contributions of fellow members of the ASME AG-1 FI Subgroup are gratefully acknowledged: Bill McAndrew (Rocky Flats), Gurinder Grewal (Fluor Daniel), Steve Klocke (Flanders). The following individuals also provided significant contributions to Article FI: Mike Whitlock (Pall Corp.), Ron Bellamy (NRC), Mike Harty (Hanford), Werner Bergman (Lawrence Livermore). The support of Christine Golden (Cook PWR), Jack Jacox (JACOX ASSOCIATES.), Curt Graves (NUCON), Richard Porco (Ellis & Watt), John Blacklaw (State of WA) is also gratefully acknowledged.

References

1. Dillman, H.-G. And Wilhelm, J.G., "Investigations into the Design of a Filter System for Pwr Containment Venting," 21st DOE/NRC Nuclear Air Cleaning Conference
2. Randhahn, H., "The Development of All-Metal Filters for Use in the Nuclear Industry," Proc. 20th DOE/NRC Nuclear Air Cleaning Conference, (1988).
3. Kaercher, M.V., "Design of a Prefilter to improve radiation protection and filtering efficiency of the containment venting system," Proc. 22nd DOE/NRC Nuclear Air Cleaning and Treatment Conference,
4. Wilhelm, J.G., "Provisions for Containment Venting in Germany," Proc. 24th Nuclear Air Cleaning and Treatment Conference.
5. Bergman, W., Conner, J., Larsen, G., Lopez, R., Turner, C., Vahla, G. Violet, C. And Williams, K. "High Efficiency Steel Filters for Nuclear Air Cleaning," 21st DOE/NRC Nuclear Air Cleaning Conference
6. Weber, L.,D.,"Technical Brief: Stainless Steel Filters for Nuclar Air Cleaning,"21st DOE/NRC Nuclear Air Cleaning Conference
7. Bergman, W., Larsen,G., Weber, F., Wilson, P., Lopez, R., Valha, G., Conner, J., Garr, J., Williams, K., Biermann, A., Wilson, K., Moore, P., Gellner, C. and Rapchun, D., "Development and Evaluation of a Cleanable High Efficiency Steel Filter," Proc. 22nd DOE/NRC Nuclear Air Cleaning and Treatment Conference,

8. Weber, L.D. and Whitlock, M.B., "Efficiency Test for Ultra High Efficiency Metal Air Filters," Proc. 22nd DOE/NRC Nuclear Air Cleaning and Treatment Conference,
9. Bergman, W., Larsen, G., Lopez, R., Wilson,K. , Witherell, C. And McGregor, M.,"Further Development of the Cleanable Steel Hepa Filter Const/benefit Analysis , and Comparison with Competing Technologies," Proc. 24th DOE/NRC Nuclear Air Cleaning and Treatment Conference.
10. Burns, D.B., Wong, A. Walker, B.W. and Paul, J.D., "Testing cleanable/reusable HEPA prefilters for mixed waste incinerator air pollution control systems," Proc. 24th DOE/NRC Nuclear Air Cleaning and Treatment Conference.
11. Weber, L.D., Rahimi, R. and Edling, D., "Validation testing of an all metal filter for radioactive waste drums," Proc. 24th DOE/NRC Nuclear Air Cleaning and Treatment Conference.

## TABLE 1
## NOMINAL HEMA FILTER SIZES AND RATINGS FOR PANEL GEOMETRY

| Number Designation | Size | | Minimum Rated Air Flow | | Maximum Resistance | |
|---|---|---|---|---|---|---|
| | Inches | mm | scfm | $M^3/hr$ | in-Wg | Pa |
| 1 | 8 x 8 x 31/16 | 203 x 203 x 78 | 25 | 42 | 2.5 | 625 |
| 2 | 8 x 8 x 57/8 | 203 x 203 x 149 | 50 | 85 | 2.5 | 625 |
| 3 | 12 x 12 x 57/8 | 305 x 305 x 149 | 125 | 212 | 2.5 | 625 |
| 4 | 24 x 24 x 57/8 | 610 x 610 x 149 | 500 | 850 | 2.5 | 625 |
| 5 | 24 x 24 x 111/2 | 610 x 610 x 292 | 1000 | 1700 | 2.5 | 625 |
| 6 | 24 x 24 x 111/2 | 610 x 610 x 292 | 1250 | 2125 | 2.5 | 625 |
| 7 | 24 x 24 x 111/2 | 610 x 610 x 292 | 1500 | 2550 | 2.5 | 625 |
| 8 | 24 x 24 x 111/2 | 610 x 610 x 292 | 2000 | 3400 | 2.5 | 625 |
| 9 | 12 x 12 x 111/2 | 305 x 305 x 292 | 250 | 424 | 2.5 | 625 |

## TABLE 2
## HEMA FILTER QUALIFICATION TEST GROUPS AND SEQUENCE

| Group | Requirement* | Test Paragraph |
|---|---|---|
| I | Resistance to rated airflow | FI-5110 |
| | Test aerosol penetration at rated airflow and at 20% of rated airflow | FI-5120 |
| | Resistance to pressure | FI-5140 |
| | Resistance to rated airflow | FI-5110 |
| | Test aerosol penetration at rated airflow only | FI-5120 |
| II | Resistance to rated airflow | FI-5110 |
| | Test aerosol penetration at rated airflow and at 20% of rated airflow | FI-5120 |
| | Resistance to rough handling | FI-5130 |
| | Resistance to heated air | FI-5150 |
| | Resistance to rated air flow | FI-5110 |
| | Test aerosol penetration at rated airflow only | FI-5120 |
| III | This section applies to Type C devices only. | |
| | Resistance to rated airflow | FI-5110 |
| | Test aerosol penetration at rated airflow and at 20% of rated airflow | FI-5120 |
| | Radiation resistance | FI-5170 |
| | Test aerosol penetration at rated airflow only | FI-5120 |
| IV | This section applies to Type C devices only. | |
| | Resistance to spot flame | FI-5160 |
| V | Resistance to rated airflow | FI-5110 |
| | Filters subjected to rated airflow with water spray. Pressure drop across clean filter not to exceed 5 times rated dry pressure drop. | TABLE FI-5100-2 |
| | Test aerosol penetration at rated airflow after drying. | FI-5120 |

*Note: Two filters, as described in Section FI-5100, shall be tested sequentially through all applicable groups.

## TABLE 3
## ("TABLE FI-5100-2," REFERRED TO IN TABLE 2, ABOVE)
## TEST CONDITIONS AND REQUIREMENTS

| Test Conditions | Test Requirements |
|---|---|
| Temperature | 95 ±5 F (35 C ±3 C) |
| Rate of airborne water droplets flowing toward the filter* | 1 ±1/4 lb/min/1000 cfm (0.45 ±0.77 kg/min/1700 $m^3$/hr) |
| Pressure differential across the filter** | 10.0 ±0.2 in. of water (2.5 kPa), or 5 times rated dry pressure differential, whichever is higher. |

*This is defined as the rate of water flowing through the spray orifice less the fallout and drainage from the air duct walls between points of location of the spray orifice and one inch before the face of the filter.

**A higher or lower differential may be specified by the owner or engineer. Pressure drop shall be monitored for 30 minutes. Up to 30 minutes may be allotted for stabilizing pressure differential before recording.

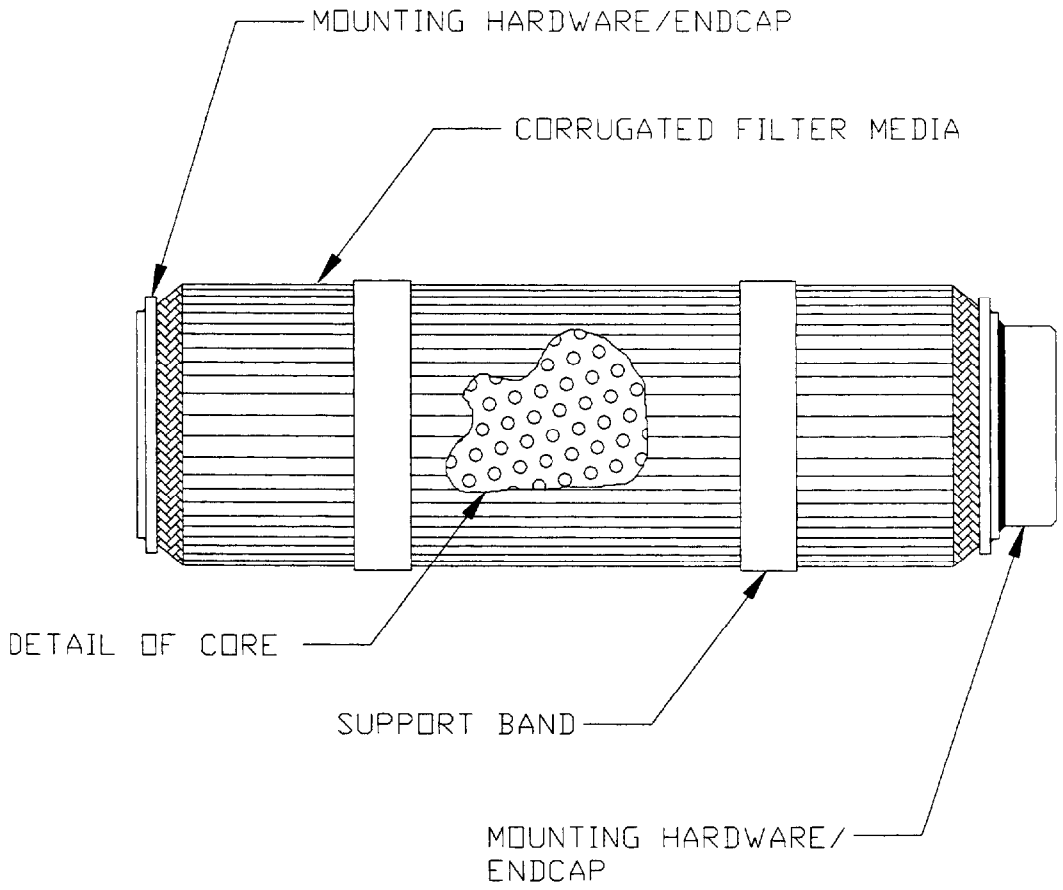


FIG. 1 EXAMPLE OF HEMA MODULE.

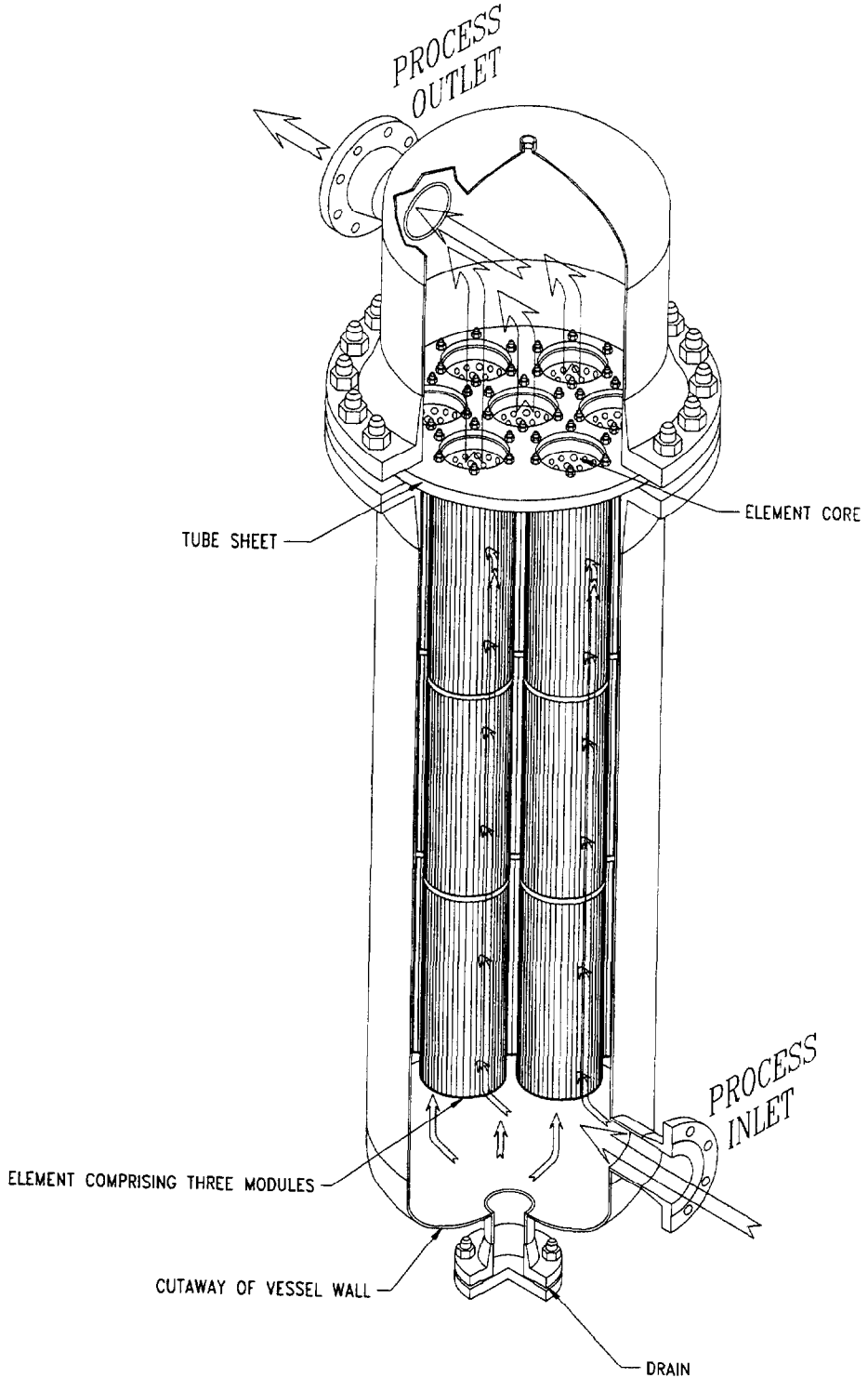


FIG.2 EXAMPLE OF HEMA ELEMENT ASSEMBLY IN PRESSURE VESSEL.

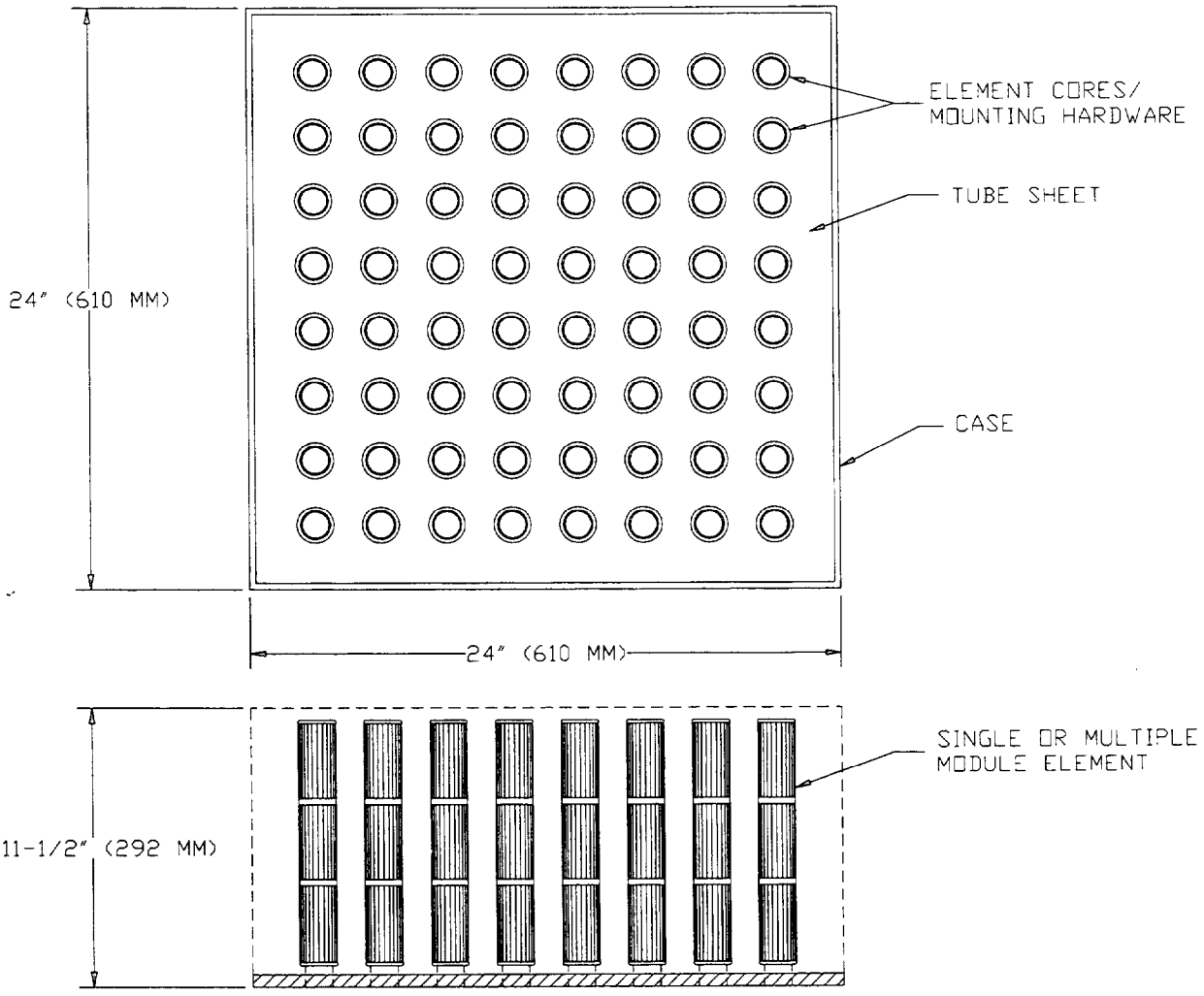


FIG. 3 EXAMPLE OF PANEL CONSTRUCTED OF HEMA ELEMENTS.