## PANELBOARD SCHEDULE

<table>
<thead>
<tr>
<th>TENANT</th>
<th>PANEL NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MANUFACTURER</th>
<th>VOLTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CAT. NO.</th>
<th>MAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MOUNT</th>
<th>MAIN BUS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CIRC</th>
<th>ITEM</th>
<th>BREAKER</th>
<th>ITEM</th>
<th>BREAKER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>TRIP</td>
<td>POLES</td>
<td>VOLTS</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL CONNECTED KVA**

**AVAILABLE FAULT CURRENT IS __________ AMPS, RMS. SYMMETRICAL**
TENANT SERVICE REQUIREMENT ELECTRICAL

TENANT SERVICE REQUIREMENT

TO BE FILLED IN BY TENANT'S ENGINEER

TENANT ___________________________ SPACE NO. __________

TOTAL DEMAND KVA = _______________ GLA _______________

DEMAND AMPS = \frac{DEMAND KVA}{\sqrt{3} \times KV} \times \sqrt{3} \times KV

DEMAND AMPS \times 1.25 = ________ (REQ'D. SERVICE CAPACITY)

REQUESTED SERVICE SIZE: ________ AMPS

WIRE & CONDUIT: __________________________

PREPARED BY: __________________________ SIGNATURE __________________________

STATE OF FLORIDA PROFESSIONAL ENGINEER LICENSE NO. ______________

FIRM __________________________ DATE __________________________

TELEPHONE NO. __________________________

SEAL

FOR LANDLORD USE

MAX. WATTS/SQ. FT. ALLOWED __________________________

_____ W/SF \times _____ GLA \div 1000 __________________________ KW

TENANT SERVICE TO BE TAKEN FROM METER ROOM NO. ______________,

SWITCH OR CIRCUIT BREAKER NO. __________________________
SAWGRASS MILLS - TENANT M.E.P. CHECKLIST

Tenant ___________________________ Space ________ GLA ________

PLUMBING
- Dom. Water (Type K/L) [Yes No N/A]
- Grease connection
- Elec. Hot Water Heater
- PVC in Plenum? [Yes No N/A]
- Water Meter; Readout
- Floor Drain

Other ____________________________

GAS/KITCHEN EQUIP.
- Equipment List [Yes No N/A]
- Emergency Shut-off
- Equip Cut Sheets
- Total CFM _______

Other ____________________________

HVAC
- Heat Gain Calc [Yes No N/A]
- Heat Loss Calc
- Duct Plan
- Outside air:
  - 10 CFM/person
  - intake location
- Damper on Return
- Fire Dampers
- Smoke Detector
- Unit Mounting Detail
- Vibration Isolation
- Duct Insulation
- Condenser Water:
  - Flow Control Valve
  - 88/100, 13 psid
- Condensate drain/pan
- Svce light/outlet
- Toilet Exhaust
- Sequence of Operation
- Compressor Interlock

Condenser Water -- Lease allowance: ________ gpm Submitted: ________ gpm

Other ____________________________

KITCHEN EXHAUST
- Duct Plan [Yes No N/A]
- Specifications
- Hood Cut Sheet (UL)
- Shop drawings
- 2" Insulation
- Sprinkler Conn
- Upblast Fan Detail
- Access doors
- MUA Backdraft Damper
- Grease Drain
- Fire Protection

Hood type: Water Wash - Filter
- Exhaust Allowance: ________ CFM 85% Make-up: ________ CFM
- Submitted Exhaust: ________ CFM Make-up: ________ CFM Total;
- ________ % direct connect

Other ____________________________

ELECTRIC
- Load Data Form [Yes No N/A]
- Power Plan
- Lighting Plan
- Panel Board Schedule
- Riser Diagram
- Current Limit Fuse
- Copper Wire
- Coreboring Plan
- Emerg/Exit Light
- Transformer Mount

Other ____________________________
SAWGRASS MILLS
TENANT SUBMISSION REQUIREMENTS

Tenants should discuss specific thoughts about their design concepts and raise any questions about their lease agreements before beginning preliminary design work.

The renderings, drawings and floor plans contained in this handbook are included for illustrative purposes to help Tenants comply with Architectural Design Criteria for Tenant Improvements. The Landlord's actual configuration and design of Sawgrass Mills, as constructed, may vary in certain aspects from such renderings, drawings and floor plans.

1. Tenants will be provided with Lease Outline Drawings describing the extent of their leased premises. The drawings will endeavor to describe all existing conditions in the individual Tenant spaces. In case of deviations between these criteria drawings and those of the Landlord’s Lease Outline Drawings, the latter will apply. The Tenant must verify all conditions in the field.

2. After receiving the Lease Outline Drawings and prior to starting construction, Tenants will provide complete working drawings and specifications for the construction of their leased premises for the Landlord’s written approval in accordance with Schedule B. The Tenant will refer to Schedule B to determine what work done by the Landlord is performed at the Tenant’s expense.

3. Tenants are required to retain the services of a professionally trained designer or architect to design their space and prepare the required drawings. Tenants are required to retain the services of a professionally trained graphic designer to design their identity programs.

4. The design submission will be completed as outlined below. Each design application is considered on its individual merit. No design will be approved until all the required documents have been received.

5. Drawings, specifications and samples must be submitted to the Tenant Coordinator as follows:

   a) One set of reproducible sepia prints on 24 inch by 36 inch paper.
   b) Six bound sets of black or blue line prints on 24 inch by 36 inch paper.
   c) Specifications, if noted on the drawings, shall be submitted on 8 1/2 inch by 11 inch paper in three sets with a plastic cover. Identify the name and space on the cover.
   d) Samples and color chips shall be firmly applied to 8 1/2 inch by 11 inch illustration board(s) and clearly labeled.
   e) Drawings must be submitted in two phases: Submission I (preliminary phase) and Submission II (final phase).
   f) All correspondence should be sent to: Sawgrass Mills, 12801 West Sunrise Blvd., Sunrise, Florida 33322, for review by the Tenant Coordinator.

SUBMISSION I

Submission I will be made as soon as the Tenant or the Tenant’s designer has completed the conceptual ideas for the particular store. The purpose of this phase is to acquaint the Landlord with the Tenant’s intentions and to fully coordinate the criteria the Tenant wishes and the building fabric before the final drawings phase. Included in this submission will be conceptual ideas for store signs.

Drawings shall include the following information at a minimum (additional information is encouraged):

1. Floor plans (scale 1/2 inch = 1 foot) indicating interior concept and method of security during off hours (large-restaurant Tenants may use 1/4 inch = 1 foot).

2. Typical interior sections (1/2 inch = 1 foot).

3. Storefront counter and partition elevations and sections (scale 3 inches = 1 foot) including graphics, dis
SAWGRASS MILLS
TENANT SUBMISSION REQUIREMENTS

Electrical drawings
(Scale: 1/2 inch = 1 foot) as follows:

1. Complete electrical drawings, floorplans and specifications.

2. Lighting layout including manufacturer's catalog numbers and catalog cuts of fixtures, installation technique, color and finish.

3. All applicable load schedules are in Book 2 of the Sawgrass Mills Tenant Handbook.

Plumbing drawings
(Scale: 1/2 inch = 1 foot) as follows: (large-restaurant Tenants may use 1/4 inch = 1 foot):

1. Complete plumbing drawings, floorplans and specifications.

2. Connection to water service.

3. Connection to soil and vent piping.

4. Complete schedules as required by Schedule E-1.

HVAC drawings
(Scale: 1/2 inch = 1 inch) as follows (large-restaurant Tenants may use 1/4 inch = 1 foot):

1. Complete HVAC drawings and specifications in compliance with all governing codes (with engineering stamp at the discretion of Landlord).

2. Proposed connection to building services.

3. Cooling and heating load calculations.

4. Complete schedules as required by Schedule E-1.

Fire protection drawings
(Scale: 1/2 inch = 1 foot) as follows (large-restaurant Tenants may use 1/4 inch = 1 foot):

1. Drawings and specifications must show alarm speakers, pull stations and sprinkler system.

2. Drawings must clearly delineate all changes Tenant wishes to make to locations, extent and number of heads, stations and speakers.

Sign submission
1. Describe sign construction and materials as well as installation techniques with detail drawings (scale: 3 inches = 1 foot).

2. Actual samples of paints and materials shall be submitted. Paint samples shall be submitted on a 12 inch long by proposed height sample of the actual size material. A letter of the actual size, style and color shall appear on the sample.

3. Include the name of sign painter and/or installer in sign submission.

4. Full-size mock-ups may be required by Landlord prior to final approval of all signs. Mock-up may be of paper, including color and finish. The Landlord reserves the right to test the sign submitted with full-size mock-ups in or on the completed building.

Security system submission
The security system must be reviewed by the Landlord to ensure consistency with the Tenant design criteria (not for the integrity of the system).

Building codes
Tenants have total responsibility for compliance with all applicable federal, state and local codes and ordinances for their occupancy type.

Tenant construction shall proceed only on the basis of drawings approved by the Landlord. Landlord's approval shall be in writing. Changes made between approved
Tenant Submission Requirements

Western Development Corporation

SAWGRASS MILLS
SAWGRASS MILLS
TENANT HANDBOOK
BOOK II

Mechanical and Electrical Design
Criteria for Tenant Improvements

WHITE BOX TENANTS

Sawgrass Mills
12801 West Sunrise Blvd.
Sunrise, FL 33322
(305) 846-1000
MECHANICAL and ELECTRICAL DESIGN
CRITERIA FOR TENANT'S IMPROVEMENTS

<table>
<thead>
<tr>
<th>I.</th>
<th>General Criteria</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>II.</td>
<td>Mechanical and Electrical Criteria</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>HVAC</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Plumbing</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Electrical</td>
<td>7</td>
</tr>
<tr>
<td>III.</td>
<td>Tenant Submission Forms and Figures</td>
<td>10</td>
</tr>
</tbody>
</table>

September 5, 1989
I. GENERAL CRITERIA

A. DESIGN

(1) The tenant's engineer shall refer to Exhibit C, LANDLORD'S WORK, and Exhibit D, TENANT'S WORK, for submission requirements and other governing criteria for the design and construction of tenant's premises. Documents governing tenant construction are the lease, lease exhibits B, C, D, and E, and the Tenant Handbooks. Exhibits C and D shall govern if there is any discrepancy between the Sawgrass Mills Tenant Handbooks and the Lease Exhibits.

(2) Complete plans and specifications, with supporting schedules and tabulations, including complete tenant data on forms provided in this Handbook, shall be prepared and submitted to the Landlord for approval in accordance with the "Tenant Submission Requirements" included as an Appendix to this Handbook.

Tenant Mechanical and Electrical drawings shall include the following, not specifically called for in the Appendix:

- Lighting Fixture Schedule, including lamp wattages for each fixture type

(3) All plans, specifications, calculations, and Tenant Data forms shall be prepared under the supervision and bear the seal of a Registered Professional Engineer holding a current valid registration in the State of Florida, in the applicable field of engineering.

(4) All work shall be done in accordance with the requirements of the Landlord's insurance carrier, NFPA Standards, and all applicable local codes and regulations. Additionally, food service facilities must adhere to the pertinent Department of Health regulations and Sanitary Codes. It is the Tenant's sole responsibility to conform to all Federal, State, and Local codes, regulations, and ordinances.

(5) Landlord's approval of Tenant's design is intended to ensure that the Tenant's design respects the limitations of the proposed Base Building systems; to ensure that the interfaces between the Tenant's systems and the Base Building systems conform to the respective limitations; and to assess that the Tenant's demand on the base building systems can be satisfied. Landlord approval does not insure satisfactory performance of Tenant systems, nor compliance with any Federal, State or Local codes, regulations, and ordinances. It is the Tenant's sole responsibility to ensure that Tenant systems will perform to the Tenant's satisfaction.

B. CONSTRUCTION

(1) Tenant work shall be performed by a General Contractor licensed and bonded in the State of Florida. All work shall be in good usable condition when completed. Tenant shall require any person performing such work to guarantee the work to be free from defects in workmanship and materials for one (1) year from date of acceptance by Landlord. Tenant shall also require any such person to be responsible for replacement or repair, without additional charge, of any and all work done or furnished within one (1) year after date of acceptance by Landlord. The correction of such work shall include, without additional charge, all expenses and damages in
connection with such removal, replacement or repair of any part of the work which may be damaged or disturbed thereby. All warranties or guarantees as to materials or workmanship on or with respect to Tenant's work shall be contained in the Contract or Subcontract which shall be so written that such guarantees or warranties shall inure to the benefit of both Landlord and Tenant, as their respective interests appear, and can be directly enforced by either. Tenant covenants to give Landlord any assignment or assurances necessary to effect the same.

(2) Tenant's work shall be coordinated with the work being performed by the Landlord and other Tenants in the building, to such extent that the Tenant's work will not interfere with or delay the completion of any other construction work in the building. Tenant shall provide public liability and property damage insurance for all work performed by Tenant's Contractors, Subcontractors and/or their suppliers in accordance with the Lease Agreement. Refer to Lease Exhibit D, Section 3. Tenant agrees to deliver to the Landlord, within 30 days of substantial completion of Tenant's construction, a complete release from all liens arising out of the Tenant's construction work.

(3) All components of Tenant's mechanical, electrical or plumbing system exposed to public view, including but not limited to ductwork, piping, conduit, insulation and hangers, shall be laid out and installed in a neat and orderly configuration, and painted by Tenant to match color and finish of surrounding Landlord's finish. Components shall be installed parallel or perpendicular to column lines.

(4) All piping and ductwork shall be installed as high as reasonably possible. All holes through structural members must be approved in advance in writing by Landlord's structural engineer (see Lease Exhibit D, Section C).

(5) Landlords' building roof structure is designed for a super-imposed loading of 4-1/2 PSF. Tenant's Engineer shall provide details showing how ceiling-hung mechanical and electrical equipment is to be supported, including the weight at each connection to the structure. Tenant must receive written permission from the Landlord's structural engineer in order to hang from the roof structure any equipment weighing over 100 lbs. per support point.

(6) Tenant shall restore any fire proofing damaged by installation of Tenant's fixtures and equipment, or damaged during the course of Tenant's construction work.

(7) For compatibility with the base building sprinkler layout, the degree of openness and the location and size of solid surfaces in Tenant's ceiling plane must comply with NFPA 13 (section 4-4), and the requirements of the authority having jurisdiction. Tenant shall not install or store anything above 12'0" aff which will interfere with the base building sprinkler coverage, including partitions, ducts, equipment, merchandise, etc.

(8) Sprinkler heads shall be required beneath any solid horizontal surfaces which are more than 47" in their smaller dimension.

(9) Tenant shall submit approved final drawings for review by Landlord's designated sprinkler contractor to ensure compatibility with the base building sprinkler design. Any modifications to the fire protection system will be designed and installed by Landlord's designated sprinkler contractor at Tenant's expense.
(10) For compatibility with the base building smoke venting scheme, Tenant's ceiling must be at least 10% free open area, uniformly distributed. Demising walls between tenant spaces above 12'0" aff must be 50% open for smoke venting (unobstructed by studs, mesh, ducts, equipment etc.), as required by NFPA standards, Landlord's Engineer, Landlord's insurance company requirements, and the authority having jurisdiction. Tenants may not use any space above 12'0" aff for storage of any kind. Figures B-1 and B-2 at the back of this Handbook illustrate the building smoke venting concept.

Any Tenant whose ceiling is less than 10% free open area shall provide smoke venting for Tenant's space. Any Tenant erecting partitions above 12'0" with less than 50% free open area shall provide smoke venting for the enclosed area(s). Tenant shall bear the cost of rearranging the original smoke venting scheme in the building to accommodate the enclosed area(s), if deemed necessary by Landlord's Engineer or the authority having jurisdiction.
Sawgrass Mills

10% Minimum Open Ceiling Area for Smoke Removal

Typical Tenant Ceiling Layout

- Fluor. Light
- Downlight
- Opening in Ceiling
Sawgrass Mills
Smoke Removal System Concept

Vertical Section

Portions above 12' off -- min 50% open area

Ceiling Grid
Min 10% open

Smoke Removal Fan

Mall Tenant Space

7/29/89 Not to Scale
II. MECHANICAL AND ELECTRICAL DESIGN CRITERIA

A. HVAC

(1) Landlord will provide a complete air conditioning system with capacity to maintain the indoor temperatures of 76 +/-2F DB, 55% RH when outdoor conditions are no higher than 91F DB or 80F WB, providing that lights and appliances with the Tenant's space do not exceed 10 Watts per square foot. Building temperature during unoccupied periods may be allowed to drop to 55F DB during the heating season.

(2) The air conditioning system will operate only during those hours established by the Landlord in accordance with the Lease Agreement.

(3) The leased premises shall have its own thermostat(s), provided and installed by Landlord, depending on the number of control zones. The thermostat(s) will control temperature within the leased premises during business hours. It will be the Tenant's responsibility to operate the system properly during all hours the Tenant is open for business.

(4) Landlord shall provide complete toilet exhaust systems if and as required by Code.

(5) No refrigeration equipment may be installed outdoors. Restaurant tenants with large refrigeration loads may cool their refrigeration equipment by outside air circulation. At Restaurant Tenant's request, Landlord's designated contractor will install louvers in the Tenant's sidewall for intake and exhaust of outside air for removing heat from refrigeration equipment, at Tenant's expense.

(6) All walk-in coolers, refrigerators and freezer boxes shall be provided with insulated floor systems as recommended by the equipment manufacturer. No walk-in cooler, refrigerator or freezer box will be permitted without the proper floor system. All walk-in boxes shall be provided with one dry sprinkler head, plus additional heads as required by Code and/or Landlord's insurance carrier. All sprinkler heads shall be installed by the Landlord's sprinkler contractor at Tenant's expense.

(7) Any Tenant determined by Landlord to produce objectionable odors within the Leased Premises shall provide an exhaust and makeup air system designed to prevent migration of odors to other Tenant spaces or to the common areas. At Tenant expense, Landlord's designated contractor shall provide and install roof curbs for each exhaust fan, and either (a) a roof jack or jacks, located as indicated on Tenant's Mechanical drawing and approved by Landlord, or (b) a louver in an outside wall and an outdoor air duct to the leased premises, which shall be used for make-up air. Tenant shall notify Landlord of dimensions and location of each required roof curb at least six weeks prior to the scheduled fan installation. Exhaust fans must be located at least 20 feet away from any outdoor air intakes, in order to avoid contaminating air supplied to other tenants. Exhaust fan locations must be submitted for Landlord approval.

(8) Any modifications or additions to the Landlord provided HVAC system shall be made in accordance with all of the requirements of the Sawgrass Mills Tenant Handbook for Rough Shell Tenants.
B. PLUMBING

(1) All tenants larger than 600 sq. ft. GLA will be provided by Landlord with a toilet room, complete with water closet, lavatory in vanity cabinet, hot water heater, and all necessary appurtenances.

(2) Landlord shall furnish and install water meters with remote readout feature for any tenants, such as hair salons and pet stores, determined by the Landlord to be high water volume users.

(3) Landlord's domestic cold water system is designed to provide a minimum pressure of 30 psig at the ceiling height of Tenant's space. If Tenant requires additional water pressure, tenant shall provide a local booster pump.

(4) Tenant shall install individual hair interceptors on all sinks, basins, and special sanitary units which may in any way receive human or animal hair. All hair interceptors must be made accessible and maintained.

(5) Any modifications or additions to the plumbing system in the Leased Premises must be made in accordance with all of the requirements of the Tenant Handbook for Rough Shell Tenants.
C. ELECTRICAL

1. DESIGN CRITERIA

(1) Electrical demand for lights and appliances within the Tenant's space shall not exceed 10 watts/sf. Electrical loads in excess of allotted amount will require a special review and written permission of Landlord. Tenant shall be charged for the additional reviews, upgrades and revisions to Landlord's distribution system.

(2) Materials, products and equipment, including components thereof, shall be new and be identified by Underwriter's Laboratories, Inc. as suitable for the purpose, and shall meet the requirements of the National Electrical Code and of local authorities having jurisdiction, and shall meet the requirements of other recognized standards, such as ASTM, IEEE, IPCEA, NFPA and NEMA, where the requirements of such standards are more stringent than those cited above.

(3) No portion of the Tenant's electrical system, including, without limitation, lighting fixtures, antennas, signs, and conduit, shall be affixed to the exterior walls or roof of Landlord's building without the specific written approval of the Landlord. Requests for such permission must be accompanied by detailed drawings showing specific details of methods of attachment and waterproofing, as well as line of sight drawings showing visibility from public areas.

(4) Landlord shall provide a complete electrical system, including 277/480 volt, three phase circuit breaker and meter socket in the main meter room, raceway and conductors to the Tenant's space, dry-type transformer, 120/208 volt, three phase, four wire panel, XXXX lighting, and XXXX receptacles. Tenant shall arrange for electrical service and metering directly from Florida Power and Light. Refer to Diagram ED-3 for a detail of the electrical system.

(5) All conductors shall be soft-drawn annealed copper. Aluminum conductors are not allowed.

(6) Tenant's circuiting on the distribution and lighting panelboard(s) shall be arranged to present, as nearly as possible, an evenly balanced load on all phases. All circuit breakers shall be bolted, thermal and magnetic breakers.

(7) The following equipment shall be identified with engraved bakelite nameplates as to name and/or function: distribution panels, lighting panels, motor starters, push button stations.

(8) All electrical work shall be installed so as to be readily accessible for operating, servicing, maintaining and repairing. Hangers shall include all miscellaneous steel, such as channels, rods, etc., necessary for the installation of the work and shall be fastened to steel, concrete or masonry, but not to piping. Hangers and supports exposed to public view must be uniformly spaced and neatly installed, with no excess material beyond what is required for the support function. Select accessories and hardware for a smooth, neat finished appearance. All conduit shall be concealed where possible. Exposed conduit shall be in straight lines parallel with, or at right angles to, column lines or beams and separated by at least 3 inches from water lines whenever they run alongside or across such lines. Conductors shall be in con-
duit, ducts or approved raceways. All exposed conduit and associated supports installed by Tenant must be painted by Tenant to match Landlord finish.

(9) Landlord will furnish and install light fixtures in the soffit of each Tenant's storefront. Each fixture will be left with a four foot whip, which Tenant shall extend to Tenant's lighting panel. Tenant shall maintain these fixtures and relamp with only the following lamp types: 150R40 FL or SP, or 120ER40.

(10) Time switches for control of merchandising zone window lighting and signs shall be seven day clock with reserve power. Time switch settings will be set up in accordance with the provisions in the Lease Agreement.

(11) Tenant's electrical demand load for lights and appliances will be based on the summation of:

- 100% of the connected lighting load; plus
- the nameplate volt-amperes for any fixed equipment; plus
- 100% of the first 10 KVA of general receptacle load, at 180 va per duplex receptacle, plus 50% of the load on the remaining receptacles; plus
- 50% of the spare breakers and spaces for future breakers, calculated at 70% of the circuit ampere rating times circuit voltage times the number of poles.

Lighting loads shall be computed based on lamp wattage for incandescent loads. For fluorescent loads, use rated lamp wattage plus ballast loss, and add a 10% power factor correction rounded off to the nearest 25 va. Tenant shall refer to the schedule on the Tenant Electrical Load Data form for demand calculations.

(12) Tenant shall perform all electrical work and shall submit all calculations in accordance with the National Electrical Code and all local code having jurisdiction, and in accordance with good engineering practice. All calculations shall conform to the appropriate articles in the National Electrical Code. Calculations shall include all branch circuits and feeder (service) tabulation. All calculations are to be expressed in va or KVA.

(13) Landlord will provide an empty telephone raceway to Telephone Company point of service at Tenant's expense. Landlord shall provide each White Box tenant with a 4'x4' plywood backboard in the tenant's space for the tenant's telephone equipment, and a single empty telephone outlet box in the tenant's space. Tenant must arrange for telephone service directly with the Telephone Company. Local Telephone Company will bring telephone service to a point inside Leased Premises as part of Tenant's Initial Service Order work by the Telephone Company. Tenant shall furnish, install, and maintain telephone wiring and equipment within Leased Premises to suit Tenant's requirements at Tenant's own expense. Tenants purchasing telephone equipment from the Telephone Company should contact the Telephone Company Business Office at 305/492-3300 to arrange for telephone service. Tenants purchasing telephone equipment from an independent telephone vendor should con-
tact the Telephone Company's Customer Operations Group at 305/599-8200 to arrange for telephone service.

(14) Tenant shall submit complete plans and specifications for Landlord's approval for all electrical work, including lighting, power and riser diagrams. Tenant shall also submit completed Tenant Electrical Load Data Form and Electrical Panel Board Schedules in the format provided by the Landlord. The tenant shall have Landlord’s written approval before any work is started.

2. MOTORS

(1) Motors shall be designed to latest NEMA Standards. Motors rated 1/2 HP and larger shall be 480 volt, three phase. Motors rated less than 1/2 HP shall be 120 volt, single phase.

(2) Manual motor starters with overload protection may be used for fractional horsepower motors. Single phase starters shall be Square D or equal. Three-phase starters shall be provided with overload relay in each phase. Magnetic motor starter shall be used for integral horsepower motors. Combination starters, when used, shall contain fusible switches. Reduced voltage starters shall be used for all motors larger than 100 HP.

3. LIGHTING

(1) Fluorescent fixtures shall be either rapid start or slimline lamps with energy saving ballast and lamps. Preheat and/or trigger start fixtures shall be used only in special applications requiring lamps less than four feet in length. All fluorescent fixtures shall have switch legs and local switches rated 20 amps at 277 V. Lamps in fluorescent fixtures shall have warm white deluxe or better color rendition.

(2) Incandescent fixtures shall be furnished and installed as required by the Tenant approved layout. No HID, Metal Halide, Mercury Vapor, etc. will be allowed.

(3) Tenant's engineer shall refer to the Architecture and Signage Criteria of the Sawgrass Mills Tenant Handbook Book I and to applicable Specific Area Criteria for specific light fixture and signage lighting requirements. Complete descriptive information must be submitted to Landlord, including pictorial representation, for approval of all lighting fixtures exposed to public view.

(4) Recessed fixtures installed in furred spaces shall be connected by means of flexible conduit and AF wire run to a branch circuit outlet box which is independent of the fixture. Fluorescent ballasts shall be high power factor, with individual, non-resetting overload protection.

(5) Landlord shall provide emergency power and emergency battery lighting within his Premises as required by Code.

(6) Landlord will furnish and install an outdoor bracket light adjacent to all Tenant exterior service doors, and wired to Tenant's electrical panel.
(1) Feeder conduit and wire by Landlord
(2) Main disconnect in Premises by Landlord
(3) Check meter socket with integration
(4) 480: 120/208 transformer by Landlord
(5) 120/208 panel by Landlord
(6) Lighting by Landlord, additional lighting by Tenant, as required
(7) Receptacles, as required by Code by Landlord, additional by Tenant, as required

Every 40 sf of demising partition,

PRELIMINARY
# Panelboard Schedule

<table>
<thead>
<tr>
<th>Tenant</th>
<th>Panel No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer</td>
<td>Volts</td>
</tr>
<tr>
<td>Cat. No.</td>
<td></td>
</tr>
<tr>
<td>Mount</td>
<td></td>
</tr>
<tr>
<td>CIRCUIT</td>
<td>ITEM</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td></td>
</tr>
</tbody>
</table>

**Total Connected KVA**

**Available Fault Current is** 1500 Amps, RMS Symmetrical.
## TENANT ELECTRICAL DATA

<table>
<thead>
<tr>
<th>TENANT</th>
<th>SPACE</th>
<th>GLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOAD ITEM</td>
<td>CONNECTED KVA</td>
<td>DEMAND FACTOR</td>
</tr>
<tr>
<td>LIGHTING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RECEPTACLES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIGNS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WATER HEATER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*COOLING EQUIPMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*REFRIGERATION MOTORS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*OTHER APPLIANCES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VENTILATION MOTORS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIR COND. MOTORS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPACE HEATING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPARE BREAKERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FUTURE BREAKERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTALS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*ATTACH SEPARATE LIST SHOWING EACH PIECE OF EQUIPMENT AND ITS NAMEPLATE ELECTRICAL DATA.*

LARGEST MOTOR IS ________ HP ________ PHASE.

Watts/sf allowance: ________ Conduit ________

Schedule C-1 KW: ________ Service Size Requested: ________

Equivalent Amps (KW/0.566): ________

Minimum Wire Size: ________ Approved Service Size: ________
AUTOMATIC HEAT AND SMOKE VENTING IN SPRINKLERED BUILDINGS

BY

EDWARD J. WARD

January, 1985
ABSTRACT

Factory Mutual believes the use of automatic heat and smoke vents in sprinklered buildings is not cost effective and may be detrimental to sprinkler control. This report presents background information in support of this position.
I  INTRODUCTION

A dichotomy now exists concerning the ability to control fire through the use of automatic vents in fully and adequately sprinklered buildings. Factory Mutual testing shows that little, if any, benefit to fire control is obtained from the use of vents. Therefore, Factory Mutual has taken the position that the high cost of installation does not justify the use of vents in sprinklered buildings. On the other hand, some organizations have taken the position that venting is an active means of fire protection, supplementing sprinkler protection.

Proponents claim that venting will aid manual fire fighting by delaying loss of visibility and reduce the risk of structural failure by venting gases with dangerously high temperatures.

Opponents believe that, in some cases, venting may even be detrimental because it draws in fresh make-up air keeping oxygen levels higher than they would be otherwise. This may cause more vigorous combustion, increase in fuel consumption and loss of sprinkler control. This report will explore the basis for this position which has caused Factory Mutual to be, perhaps, the most outspoken opponent of venting.

II  BACKGROUND

2.1 Early FMRC Testing

As early as 1956, Factory Mutual Research Corporation recognized that the effects of venting are different in sprinklered buildings than in unsprinklered buildings. A research project entitled "Heat Vents and Fire Curtains, Effect on Operation of Sprinklers and Visibility" was conducted in a 120 X 60 ft test building equipped with 5 ft draft curtains and vent area ranging up to 32 ft$^2$ within a curtain area of 2280 ft$^2$. This is a vent ratio of about 1:70 - that is 1 ft$^2$ of vent area for every 70 ft$^2$ of floor area. A 5 gal/min gasoline spray fire was used as the exposure, and protection consisted of 160°F automatic sprinklers installed on a 10 X 10 ft spacing.

A series of tests was conducted using various combinations of vents, draft curtains and sprinklers. Six of these were sprinklered tests. (See Table 1.)
Table I
TEST VARIABLES

<table>
<thead>
<tr>
<th>TEST NO.</th>
<th>VARIABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No curtain, no vent, 15 gpm</td>
</tr>
<tr>
<td>2</td>
<td>No curtain, 32 ft² vent, 15 gpm</td>
</tr>
<tr>
<td>3</td>
<td>5 ft curtain, 32 ft² vent, 15 gpm</td>
</tr>
<tr>
<td>4</td>
<td>5 ft curtain, 16 ft² vent, 15 gpm</td>
</tr>
<tr>
<td>5</td>
<td>5 ft curtain, no vent, 15 gpm</td>
</tr>
<tr>
<td>6</td>
<td>5 ft curtain, no vent, 25 gpm</td>
</tr>
</tbody>
</table>

Results of these six tests are shown in Table II. When comparing
the number of sprinklers operating in each test, note the following:

1. In vented Test 2, the number of operating sprinklers was reduced by
   four over Test 1 without vents.

2. The installation of draft curtains significantly reduced the number
   of sprinklers operating as evidenced by Tests 3 through 6 compared
   to Tests 1 and 2. It should be pointed out, however, that consider-
   ably more sprinklers probably would operate if the fire origin
   was near the intersection of two or more curtained areas.

3. Vented Tests 3 and 4 were slightly better than the similar, but
   unvented, Test 5.

4. Lastly, and most importantly, the greatest reduction in sprinkler
   operation occurred in Test 6 due to the increased sprinkler
   discharge.

Table II
TEST RESULTS

<table>
<thead>
<tr>
<th>TEST NO.</th>
<th>NUMBER OF SPRINKLERS OPERATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>48</td>
</tr>
<tr>
<td>2</td>
<td>44</td>
</tr>
<tr>
<td>3</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td>28</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
</tr>
</tbody>
</table>

Average temperatures are shown in Table III for both unsprinklered
and sprinklered tests in three areas. The first is 2 ft outside the curtained
area, the second is the average within the curtained area, and the third is
within the curtained area 7 ft from the fire. Comparison of average tempera-
tures indicates that vents contributed significantly to temperature reductions
in the unsprinklered tests; however, they were of marginal value in the sprin-
klered tests. In all 3 cases, the greatest temperature reduction occurred
when no vents were used and the sprinkler discharge was 25 gal/min.

Visual observations during these tests indicated that visibility in the building bays adjacent to the fire area was generally reduced to zero after about 6 minutes. In the vented tests, visibility in bays remote from the fire was improved as compared to the unvented tests.

Although this project was conducted 26 years ago, it did indicate that the interaction of vents and sprinklers required additional study before vents could be considered advantageous in a sprinklered building.

### TABLE III

**AVERAGE TEMPERATURES (°F) AFTER 15 MINUTES**

<table>
<thead>
<tr>
<th>Sprinkler Flow</th>
<th>NO VENT</th>
<th>16 FT² VENT</th>
<th>32 FT² VENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 FT OUTSIDE CURTAINED AREA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Sprinklers</td>
<td>800</td>
<td>500</td>
<td>235</td>
</tr>
<tr>
<td>15 gal/min</td>
<td>190</td>
<td>190</td>
<td>160</td>
</tr>
<tr>
<td>25 gal/min</td>
<td>130</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**WITHIN CURTAINED AREA**

<table>
<thead>
<tr>
<th>Sprinkler Flow</th>
<th>NO VENT</th>
<th>16 FT² VENT</th>
<th>32 FT² VENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Sprinklers</td>
<td>1150</td>
<td>960</td>
<td>770</td>
</tr>
<tr>
<td>15 gal/min</td>
<td>630</td>
<td>560</td>
<td>480</td>
</tr>
<tr>
<td>25 gal/min</td>
<td>220</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**7 FT FROM FIRE**

<table>
<thead>
<tr>
<th>Sprinkler Flow</th>
<th>NO VENT</th>
<th>16 FT² VENT</th>
<th>32 FT² VENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Sprinklers</td>
<td>1900</td>
<td>1660</td>
<td>1440</td>
</tr>
<tr>
<td>15 gal/min</td>
<td>1500</td>
<td>1520</td>
<td>1460</td>
</tr>
<tr>
<td>25 gal/min</td>
<td>1300</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### 2.2 FMRC Model Study

In the early 1970's, Dr. Gunnar Heskested of FMRC conducted a study entitled "Model Study of Automatic Smoke and Heat Vent Performance in Sprinklered Fires." The objective of this test program was to investigate experimentally the performance of automatic heat and smoke vents for sprinklered fires in one-story buildings, principally in terms of sprinkler water demand, but also in terms of visibility conditions and fuel consumption. The study was performed in a 1:12.5 scale model at Norwood of FMRC's fire test facility at West Glocester, R.I. Automatic, individually fused vents on 50-ft spacing were employed, often in combination with a draft curtain (10,000-ft² curtained area).

Of primary interest were venting installations conforming to recommendations of standards-setting bodies which were current at the time. For a cellulose fire opening about fifty 212°F sprinklers at a density of 0.27 gal/min/ft² vents alone (without draft curtains) had no effect on the water
demand, but delayed loss in visibility from 13.1 to 15.7 min and increased fuel consumption by 31 percent. Vents and draft curtains caused a 35 percent increase in water demand relative to the unvented fire. Delayed loss in visibility from 13.1 to 20.2 min, and increased fuel consumption by 66 percent.

Unambiguous, favorable effects of venting were only observed for a series of large, heptane fires, opening an average of 112 sprinklers at 0.27 gal/min/ft². Vents alone reduced the water demand by 8 percent and markedly improved visibility conditions; vents and draft curtains reduced the water demand by 18 percent, but did not improve visibility conditions as much as without draft curtains.

These results pertain to ignition points equidistant from the four nearest vents in the vent matrix. Experiments with ignition directly under a vent indicated that some reduction in water demand can be expected also for fires opening 50 sprinklers or less. It was concluded, however, that for randomly starting fires, less than about 13 percent of the fires would benefit from closeness to a nearby vent.

2.3 IITRI Testing

In the early 1980’s, a series of tests was conducted at the Illinois Institute of Technology (IITRI) in Gary, Indiana, to examine the interaction of automatic roof vents and automatic sprinklers. The prime objective of this study was to determine if venting was detrimental to sprinkler control claimed to be the Factory Mutual position.

While Factory Mutual was a participating technical member of the Fire Venting Research Committee that sponsored these tests, FM was not a funding member and took exception to the conclusions reached by the author, both during the report preparation and review stages and after report publication. Appendix A contains an internal memorandum which is a technical review by Dr. Heskestad of the IITRI report. This memorandum was submitted to the National Fire Protection Association during review of a proposed revision of Chapter 6 of NFPA 204M, "Guice for Smoke and Heat Venting" submitted by the author of the IITRI test work. As a result, it is public knowledge.

2.4 Large Scale Testing

Factory Mutual has not conducted large scale tests of any kind to specifically examine the effects of venting on fire control by sprinklers. The test site in West Grocester, R.I. is not equipped with roof-mounted vents and its false ceiling design precludes normal vent installation. It is, however, equipped with eave-line windows which can be operated from the test site control room.

It is important to note that most of the large scale tests were conducted without venting of any type (overhead or eave-line) being employed. Test results could be significantly different if venting had been used. In the FMRC model study of the 1970's, the conclusion on increased fuel consumption was based on the premise that for effective venting to occur, fresh inlet air is needed to replenish the gases being vented. As a result, an environ-
ment with a higher oxygen content is developed contributing to a more vigorous fire and greater fuel consumption than would occur without venting.

Due to the above findings, Factory Mutual storage standards state:

"Factory Mutual recommended protection is based on roof vents and draft curtains not being provided. Fire tests have not shown automatic vents to be cost effective and they may even increase sprinkler water demand. Hence, permanent heat and smoke vents, if any, should be arranged for manual operation. Smoke removal during mop-up operations can frequently be achieved through eaveline windows, doors, monitors, non-automatic exhaust systems (gravity or mechanical) or manually operated heat and smoke vents. Fire departments can cut holes in steel or wood roofs and also use their smoke exhausters."

More than 80 full scale rack storage tests were conducted between 1968 and 1975. Only three tests employed perimeter ventilation during the test and only two of these three (Nos. 72 and 73) were identical to two other tests (Nos. 65 and 66) except for the ventilation variable. Results of these tests are shown in Table IV.

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Ventilated</th>
<th>Number of Ceiling Sprinklers Operating</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>No</td>
<td>45</td>
</tr>
<tr>
<td>66</td>
<td>No</td>
<td>48</td>
</tr>
<tr>
<td>72</td>
<td>Yes</td>
<td>92</td>
</tr>
<tr>
<td>73</td>
<td>Yes</td>
<td>30</td>
</tr>
</tbody>
</table>

Depending on which tests are compared, venting can show either a moderate improvement or a dramatic detriment. Factory Mutual's position on the effects of ventilation in these tests is that they are not conclusive.

The effect of ventilation on fire control was best demonstrated during Factory Mutual's large scale fire testing of rubber tires in 1970. This test was made to evaluate sprinkler protection for automobile tires stored in portable steel racks. Storage was located in a single pile 35 ft x 50 ft x 18 ft high. Protection consisted of 286°F, 1/2 in. sprinklers spaced 50 ft² each with a controlled discharge of 0.6 gal/min/ft². There was no ventilation at the start of the test.

The fire was started at the base of a rack. The first sprinkler operated 2 min. 15 sec. after ignition. By 8 min. 20 sec., 43 sprinklers had operated and controlled the fire. Only one additional sprinkler operated at 28 min. The fire remained under control until 60 min. into the test when all doors and windows were opened to ventilate the building and sprinklers were left on. The fire then began to spread and grow in intensity. At 117 min. when it was apparent that sprinklers were failing to control the fire, all doors and windows were closed. A total of 95 sprinklers operated and water was discharged for over 5 hours. Only the 95th sprinkler operated after doors
and windows were closed and that was at 118 min., 1 min. after closure.

III NFPA 204M, GUIDE FOR SMOKE AND HEAT VENTING

The 1982 NFPA guide for designing venting is limited in scope to unsprinklered buildings. The technology does not exist today to determine the vent area needed in a sprinklered building due to the complex fluid dynamics involved, primarily due to the cooling action of water. Chapter 6 discusses sprinklered buildings and states, essentially, that there is no universal opinion on the benefits or adverse effects of venting a sprinklered building and the designer is urged to use available data to solve a particular problem.

After the IITRI tests were conducted, the author of those tests proposed changes to Chapter 6 which stated in part that "automatic roof venting can provide two major contributions to (165°F) sprinkler protected (large, one-story) properties.

1. Perform as vents in unsprinklered properties, should installed sprinklers be defeated by human failure or mechanical means.

2. Substitute for manual roof venting upon arrival of the fire services.

Primarily on the basis of No. 1 above, it is recommended that, where so used, the design and installation of automatic roof vents for sprinklered properties follow guidance for unsprinklered properties."

Factory Mutual opposed this action and made public comments to amend the proposed Chapter 6. These comments were accepted with editorial changes by the Building Construction Committee and are shown in Appendix B. The revised Chapter 6 is also shown in Appendix B and will be presented at the NFPA Annual Meeting in Chicago in May, 1985. The Advisory Board's comments on this position will be appreciated.

IV ADVANTAGES/DISADVANTAGES OF VENTING

4.1 There are several reported advantages of venting, including the following:

1. Improved visibility (as compared to the same situation without vents).

2. Reduced ceiling temperatures, possibly preventing roof collapse.

3. Substitution for manual venting by the fire department.

It is an established fact that venting will delay loss of visibility in either a sprinklered or unsprinklered building. As stated previously,
knowledge does not presently exist to design a venting system to maintain a clear layer in a sprinkled building.

For unsprinkled buildings, NFPA 204M gives design guidelines for determining vent area based on the "heat release rate" of the commodity located within the building. For sprinkled buildings, the "net heat release rate" must be determined. It is defined as the heat release rate minus the heat absorption rate by discharged water and surroundings.

This formula may be theoretically correct, but the technology does not presently exist to make this prediction. Furthermore, production of steam and the cooling action of sprinkler water driving gases to floor level will, by themselves, obscure visibility. While venting will delay loss of visibility, it will not prevent loss of visibility.

It is extremely unlikely that typical vent installations (such as 1 ft² vent area to 75-100 ft² floor area) will vent enough heat from a major fire to prevent structural steel failure when sprinklers are not operating or when the water supply is not adequate for the fire hazard. A perfect example of this is the $110,000,000 K-Mart fire which occurred in a building containing vents installed on a 1:96 ft² ratio. In this case, within 15 minutes after ignition, fire was burning through the roof.

Appendix C contains an example of the needed vent area for a theoretical unsprinkled building, calculated in accordance with NFPA 204M. This vent area is needed to maintain a clear area near floor level for only 10 minutes while at the same time preventing steel failure. It must be pointed out that this is not a method recommended by NFPA or FM for sprinklered buildings. It is an example only, intended to illustrate the excessively large vent areas that are needed. This theory cannot be realistically used in sprinklered buildings because the fresh inlet air could produce a more vigorous fire of faster growth time or greater heat release rate, possibly defeating the design principles.

The vent ratio for this example is 1:2.3, or stated differently, vents occupy 44% of the roof area. The cost of installing vents, curtain boards and special provision for inlet air for this system would likely be in excess of $100,000, exceeding the cost of an installed sprinkler system.

4.2 The disadvantages of venting include the following:

1. The high installation cost for questionable value.

2. The increased fuel consumption associated with the higher oxygen supply from inlet air. A fire which may be capable of borderline sprinkler control could burn more vigorously when vents open, and control could be lost.

Most sprinkler arrangements and water supplies recommended for warehouse storage by NFPA and FM result from rigorous testing at FM's Test Center. Most arrangements employ little safety factors. The introduction of
a new and major variable, such as venting, without a similar series of tests could adversely affect adequate protection currently employed.

V CONCLUSION

The high installation cost of vents is difficult to justify when one considers the limited benefits and possible detriment. It is the Factory Mutual position that vents are not cost effective. They are not cost effective because it is unlikely a large loss will be averted solely due to the presence of vents when automatic sprinkler protection is inadequate or impaired.

Venting may or may not be detrimental, depending on many factors, such as the location of the fire origin in relation to the location of vents. Dr. Heskestad concluded that more often than not, vents will increase the water demand. Even when automatic vents result in some improvement, the improvement is not required for sprinklers to gain control. On the other hand, vents can create conditions which will inhibit or prevent sprinkler control.

Installing automatic vents in unsprinklered buildings is acceptable to Factory Mutual. It would certainly be more beneficial to the building owner, however, to install sprinklers rather than vents to obtain active rather than passive fire control.

Installing manual vents in a sprinklered building is also acceptable to Factory Mutual, if desired by the building owner. These vents can be of use during manual overhaul or at locations which would be expected to produce dense smoke. However, a similar effect can be achieved by venting through windows, by fire fighters cutting holes in the roof or by ventilation equipment or smoke exhausters.
INTEROFFICE CORRESPONDENCE

TO    E.J. Ward
FROM  G. Heskestad

DATE February 8, 1983

Abstract

This is a review of a report which describes an investigation on the interaction of roof fire vents with sprinklered fires. The reviewer does not agree that the experimental results support the main conclusion of the investigation, which is that automatic roof vents do not impair sprinkler control of fires capable of growth.

1. Introduction

The subject report describes an experimental study on the effect of automatic roof vents on sprinklered fires. According to the authors, the experimental results suggest that the ability of 165°F rated automatic sprinklers to control, or nearly control, a fire otherwise capable of growth, in a large one-story structure, is not impaired by the presence of automatic (roof) fire vents of typical spacing and area."

The authors claim that automatic roof vents can provide two major contributions to sprinkler-protected properties:

"Perform as vents in unsprinklered properties, should installed sprinklers be defeated by human failure or mechanical damage."

and:

"Substitute for manual roof venting upon arrival of the fire services."

The finding that automatic roof vents do not impair the ability of 165°F sprinklers to control fires capable of growth contradicts some well-known previous studies, which have indicated that the increased availability of oxygen associated with open vents may lead to increased fire intensity (of fires capable of growth), water demand and consumption of combustible.
It is concluded in this review that the reported results do not justify the overall conclusions and recommendations quoted above. The investigation suffers from a number of defects: 1) situations claimed to be unvented were not; 2) one of the most important principles of venting was violated, i.e., the provision of adequate openings for inlet air; and 3) inadequate control was exercised over the experimental conditions to the extent that major variations observed in fire behavior cannot be attributed to the parameter under study: venting.

2. Experimental Facility

The top of Figure 1 is a reduced copy of Figure 3 in the report (dimensions added), showing the test building and the corner fire location, together with sprinklers and roof vents. At the right end of the test building are two venting stacks which were installed to simulate availability of air from additional bays, one exhausting hot gases flowing under the "draft curtain" and another returning fresh make-up air. The bottom of Figure 1 illustrates the building and fire situation simulated, the simulated building being four times larger than the actual test building, with a fire in the center.

The venting stacks consisted of one pair of exhaust stacks and one pair of intake stacks. The exhaust stacks are properly considered to be vents of venting capacity, per unit vent area, practically equal to the roof vents for situations where the smoke level has descended to the exhaust vent openings. Each of the roof vents E1,E2,W1,W2 was 32 ft$^2$ in area, compared to a total vent area of 72 ft$^2$ for the exhaust stacks. The total flow area of the intake stacks was 72 ft$^2$ as well, constituting the only openings for inlet air.

In the report, closed roof vents are considered synonymous with no venting. In actuality, the building was vented through the 72 ft$^2$ exhaust stacks with intake through the 72 ft$^2$ intake stacks. According to Figure 2, taken from Thomas et al.*, the resulting ratio of inlet area to outlet area of one (1) was large enough so that the inlet area did not restrict the vent flow appreciably (effective or "corrected" vent area equal to 0.81 times actual vent area, according to Figure 2). With roof vents in operation, the ratio of

TANKER BUILDING (BOTTOM).

SECTION 1: TEST BUILDING WITH ROOF VENTS AND SPROKET (TOP) AND SIMILAR.
Effect of area of inlet on corrected area of vent

FIGURE 2.
inlet area (72 ft$^2$) to total vent area (72 ft$^2$ + area of roof vents) could be considerably smaller than one, implying, according to Figure 2, that the effective ("corrected") vent area would be significantly smaller than the geometric vent area. Table I lists effective vent areas* according to the number of roof vents open, as determined with the aid of Figure 2 ("500 deg F"). Note that, as the number of roof vents varies from 0 through 4, the effective vent area increases from 58 to 88 ft$^2$, i.e., only by about 50 percent. Also observe that after two roof vents have opened, additional roof vents contribute insignificant effective vent area.

3. Experiments

There were four experimental series, two with propane diffusion burners as fire source and two with stacks of wood pallets as fire source.

The first propane series was not considered particularly useful by the authors, primarily because the initial configuration of venting stacks (different from that in Figure 1) provided inadequate venting to even keep the burners lit (oxygen starvation).

The second propane series did employ the venting stacks in Figure 1. Vents, when configured for automatic operation, were equipped with 165°F fusible links and the sprinklers were rated either 165°F or 286°F. With sprinklers rated 165°F, 9 sprinklers nearest the corner fire operated with no open roof vents (vents prevented from opening). This number remained unchanged with one automatic roof vent open (W2, with W2 and E2 active), decreased to 8 with two automatic roof vents open (W1 and W2, with all vents active) and then decreased further to 7 with all four roof vents open at the start of the test. Generally, one expects that a roof vent will reduce gas ceiling temperatures primarily in the region beyond the vent, opposite the side of the fire. Since only about two of the nine sprinklers which operated without open roof vents were located in the region expected to be cooled by the vents (Figure 1) and the heat output of the propane burners could not be affected, one might have anticipated the rather minor effect observed on the number of operated sprinklers. For

*The effective vent areas have not been corrected for the aerodynamic discharge coefficients, which would reduce all areas by a factor of about 0.6.
**TABLE I**

**EFFECTIVE VENT AREAS ASSOCIATED WITH NUMBER OF ROOF VENTS ACTIVATED**

<table>
<thead>
<tr>
<th>No. Roof Vents Activated</th>
<th>Geometric Vent Area (ft²)</th>
<th>Inlet Area Vent Area</th>
<th>Effective (or &quot;Corrected&quot;) Vent Area (ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>72</td>
<td>1.00</td>
<td>.58</td>
</tr>
<tr>
<td>1</td>
<td>104</td>
<td>0.69</td>
<td>73</td>
</tr>
<tr>
<td>2</td>
<td>136</td>
<td>0.53</td>
<td>82</td>
</tr>
<tr>
<td>3</td>
<td>168</td>
<td>0.43</td>
<td>86</td>
</tr>
<tr>
<td>4</td>
<td>200</td>
<td>0.36</td>
<td>88</td>
</tr>
</tbody>
</table>
sprinklers rated at 286°F, the test team decided to reduce the water pressure to bring the number of sprinklers operated with no open roof vents up to 8. Two open automatic roof vents (W2 and E2, the only active vents) decreased the number of operated sprinklers to 6. However, with four open automatic roof vents (all vents active), 7 sprinklers operated.

The results from the second propane series cannot be said to be unexpected. The slight reduction observed in water demand (number of sprinklers operated) with roof vents is attributed to cooling of the ceiling gas layer beyond open vents. If sprinklers normally (without roof venting) do not open beyond the location of the set of vents nearest the fire, one may not expect significant reductions in water demand with roof vents. Incidentally, it is useful to keep in mind that the 6-9 sprinklers which operated in the second propane series correspond to 24-36 sprinklers in the simulated, larger building (bottom, Figure 1).

While the nonpropagating, propane fires were of peripheral interest, the propagating, wood-pallet fires provided the main data base of this investigation. These fires should have revealed the net effect of venting on water demand, fuel consumption and visibility. They did not.

All wood-pallet fires were conducted with 165°F rated sprinklers. The first wood-pallet series included several runs with varying number of pallet stacks, stack height, shielding on top of the stacks, and reduced water pressure, all for the purpose of raising the fire severity and the number of automatic sprinklers which operated. This series included only three tests under nominally similar conditions except the degree of roof venting. Among these, two tests without roof vents operated 21 and 4 sprinklers, respectively. In the third test with all roof vents open at the start, 12 sprinklers opened. No conclusions on the effect of roof venting could be drawn, or were drawn, from these tests. The authors speculated that the poor reproducibility in the tests without roof vents was related to small differences in pallets and pallet stacks and to the ability of the water pump operator to provide constant delivery pressure to the sprinkler system. However, the range 4-21 sprinklers which operated with no roof vents, corresponding to 16-84 sprinklers in the simulated building, is too large to be explained by small differences in fuel and water flow.
The second wood-pallet series employed a modified ignition technique, believed to be an improvement by the test team. The test series consisted of alternating tests with 1) no roof venting and 2) automatic venting through vents W2 and E2 (Figure 1). The fire source was a four-stack array of wood pallets covered completely by a plywood shield. After the two first tests, the supply of the standard test pallet ran out and could not be replenished; a new type pallet was employed for the rest of the program. Of the two first fire tests, one was without roof vents and opened 15 sprinklers; the other activated vents W2 and E2 and opened 22 sprinklers, the total installed. The first test with the new type pallet was conducted without a plywood shield and was thrown out because it opened so few sprinklers (4). All the other tests with the new pallet type incorporated the plywood shield. Without roof vents, the spread in number of operating sprinklers, in the total of five tests, was 7-22. In tests where vents W2 and E2 could open automatically, both vents opened in four of five tests and one vent opened in the remaining test; the spread in the number of operating sprinklers was now 12-20. The authors state:

"it is hard to discern any trend in results due to operation of vents."

Any consistent effect of roof venting could not be discerned in any of the following measurements: water demand (number of sprinklers), temperature over pallet fires, temperature at remote locations, and oxygen concentration of air entering fuel bed. There were wide variations in these measurements from test to test, but the variations were dominated by other factors than the roof vents. On the basis of such clearly inconclusive results, the authors formed the overall conclusion, quoted in the Introduction, to the effect that automatic roof vents do not impair sprinkler control of fires capable of growth. This conclusion has no foundation in the results presented in the report.

It is not known what variables were responsible for the wide variations observed in fire behavior during the second wood-pallet test series. That no consistent effect of roof venting could be discerned might be explained by Table I, which indicates that the effective vent area for no roof vents was not much less than that for two activated vents, 58 ft² versus 82 ft².
4. **Closure**

   It has been concluded that the experimental results of this report do not support the overall conclusion of the report to the effect that automatic roof vents do not impair sprinkler control of fires capable of growth. Consequently, the design recommendations in the report that automatic roof venting can be used as backup in the event sprinklers malfunction, or can be used to substitute for manual roof venting, are no better justified now than before.

   cc:  R. Friedman  
        C. Yao
APPENDIX B

NFPA PUBLIC COMMENTS

204M-1 (6-3): Accept in Principle
SUBMITTER: Edward J. Ward, Factory Mutual Research Corporation
COMMENT ON PROPOSAL NO.: 204M-1
RECOMMENDATION: Replace 6-3 with following proposed wording:
6-3 A series of tests was conducted to increase the understanding of the role of automatic roof vents simultaneously employed with automatic sprinklers (Section 6-5(c)). Due to the many uncontrolled variables involved, no conclusion could be reached whether sprinkler control was impaired or enhanced by the presence of automatic (roof) vents of typical spacing and area.
SUBSTANTIATION: IITRI's Project J06385 did not substantiate the conclusions reached. As a result, Section 6-3 is misleading. This study suffers from a number of defects, including:
(1) situations claimed to be unvented were not; (2) one of the most important principles of venting was violated, i.e., the provision of adequate openings for inlet air; (3) inadequate control was exercised over the experimental conditions to the extent that major variations observed in fire behavior cannot be attributed to the parameter under study: venting. For further substantiation, refer to Dr. Heskestad's memorandum, "Review of 'Fire Venting of Sprinklered Buildings' by Waterman et. al." available at NFPA Headquarters.
COMMITTEE ACTION: Accept in Principle.
Replace 6-3 with the following:
6-3 A series of tests was conducted to increase the understanding of the role of automatic roof vents simultaneously employed with automatic sprinklers (Section 6-5(c)). The data submitted did not permit consensus to be developed whether sprinkler control was impaired or enhanced by the presence of automatic (roof) vents of typical spacing and area.

COMMITTEE COMMENT: The submitter's wording, with committee-generated revisions as shown above, is accepted in principle because it clarifies the Committee's intent. The new wording reflects the difficulty the Committee encountered in its deliberations in trying to develop a consensus on the research results of the IITRI project.
APPENDIX B

Chapter 6 - Venting in Sprinklered Buildings

6-1 Two popular elements of hazard control have been developed over the years, namely, sprinklers and vents. Each was developed independent of the other. The previous sections represent the state of technology of vent design in the absence of sprinklers. An equivalent, generalized design basis for using both sprinklers and vents together for hazard control (e.g., property protection, life safety, water usage, obscuration, etc.) has not been developed and is not presently available.

6-2 Concern has been raised that inclusion of automatic roof venting may be detrimental to the performance of automatic sprinklers. Although there is no universally accepted conclusion from fire experience (Section 6-6(a)), studies on a model scale (Section 6-5(b)) suggested:

(a) Venting delays loss of visibility.

(b) Venting results in increased fuel consumption.

(c) Depending on the location of the fire relative to the vents, the necessary water demand to achieve control is either increased or decreased over an unvented condition. With the fire directly under the vent, water demand is decreased. With the fire equidistant from the vents, water demand is increased.

6-3 A series of tests was conducted to increase the understanding of the role of automatic roof vents simultaneously employed with automatic sprinklers (Section 6-5(C)). The data submitted did not permit a consensus to be developed whether sprinkler control was impaired or enhanced by the presence of automatic (roof) vents of typical spacing and area.

6-4 While the use of automatic venting in sprinklered buildings is still under review, the designer is encouraged to use the available tools and data referenced in this document for solving problems peculiar to a particular type of hazard control.

6-5 References of interest include:

(a) Miller, E.E., Position Paper to 204 Subcommittee, Fire Venting of Sprinklered Property.


APPENDIX C

Given:

1. Building dimensions = 120 ft x 600 ft x 30 ft.
2. Roof = flat steel deck construction.
3. Occupancy = 15 ft. high palletized storage of polyethylene bottles in cardboard cartons.
4. Curtain boards extend down 6 ft from the roof and are spaced every 60 ft.

Calculate total number of 165°F fusible link actuated, 4 ft x 8 ft vents needed to maintain a minimum clear visibility design time of 10 minutes.

From Table 4-3 of NFPA 204M, a vent area of 1600 ft² is needed within each compartmented area of 3600 ft². This equates to fifty 4 ft x 8 ft vents per compartment, or 1000 vents throughout the building. Additionally, inlet air area must be at least equal to the total vent area per compartment.
The fire model used for the Sawgrass Mills shopping Mall was the ASET-B, Version 1.0 developed at the National Bureau of Standards in Gaithersburg, Maryland. This program is used to predict average smoke layer temperature, depth and heat output versus time.

For Sawgrass Mills, the primary objective was to calculate the height of the smoke layer above the mall floor versus time. Such a calculation is important for predicting the amount of time available for safe egress from the building.

To introduce an additional level of conservatism in the results (beyond that which is inherent in the ASET-B program), the following assumptions were made:

- The "mall" volume considered includes the floor area of the entire building (excluding anchor stores) multiplied by the roof deck height of 18 feet above the floor.
- No automatic sprinkler protection was provided.
- No smoke exhaust or venting was provided.
- A medium fire begins and is allowed to grow in an uncontrolled fashion throughout the building, i.e., no active fire suppression was provided. (In the terminology of the computer program, a "medium fire" was chosen as being representative of the type of fire expected in a shopping mall. Factors taken in account are expected rates of fire growth and heat release.)
- A Heat Loss Fraction of 0.8 was assumed, indicating the percentage of heat absorbed by surrounding building components.

As is evident from the data, the smoke layer has not descended below the 17 foot level, even after 2,010 seconds (33.5 minutes) of fire development. At this time, an approximate cumulative volume of 960,000 cubic feet of smoke would have been generated.
Three important conclusions to the data are as follows:

1. There is adequate time for building occupants to exit in the event of a fire. The building is a single-story structure with a maximum exit travel distance of 400 feet. Since studies show that the average walking speed is about 150 feet per minute under the expected occupant loading for a covered mall, total evacuation may be achieved in about three minutes.

2. The fire model assumed that no automatic suppression was available. In fact, a fully supervised automatic sprinkler system will protect the premises. Under the conditions described, it is expected that sprinkler actuation would occur approximately 7.5 minutes after the start of the fire. At this time, the fire should be extinguished or at least controlled, severely limiting further liberation of smoke and toxic gases.

3. If the fire were allowed to grow in an uncontrolled fashion (no sprinklers), the rate of smoke production would increase with respect to time. Even after an excessive 33 minutes from the start of the fire, smoke would be generated at the rate of approximately 60,000 cubic feet per minute (cfm). Since the proposed mechanical smoke evacuation system is capable of exhausting about 2.4 million cfm, the building would be maintained relatively clear of smoke for well in excess of 33 minutes.
<table>
<thead>
<tr>
<th>TIME</th>
<th>TEMP</th>
<th>TEMP</th>
<th>LAYER</th>
<th>LAYER</th>
<th>FIRE</th>
<th>FIRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>sec</td>
<td>°F</td>
<td>°C</td>
<td>ft</td>
<td>ft</td>
<td>W</td>
<td>BTU/s</td>
</tr>
<tr>
<td>0.0</td>
<td>76.0</td>
<td>24.4</td>
<td>16.0</td>
<td>5.5</td>
<td>8.1</td>
<td>8.1</td>
</tr>
<tr>
<td>26.0</td>
<td>76.0</td>
<td>24.4</td>
<td>16.0</td>
<td>5.5</td>
<td>16.0</td>
<td>16.0</td>
</tr>
<tr>
<td>66.0</td>
<td>72.0</td>
<td>22.2</td>
<td>16.0</td>
<td>5.5</td>
<td>14.0</td>
<td>14.0</td>
</tr>
<tr>
<td>92.0</td>
<td>70.0</td>
<td>21.1</td>
<td>16.0</td>
<td>5.5</td>
<td>12.9</td>
<td>12.9</td>
</tr>
<tr>
<td>129.0</td>
<td>68.0</td>
<td>20.0</td>
<td>16.0</td>
<td>5.5</td>
<td>11.8</td>
<td>11.8</td>
</tr>
<tr>
<td>156.0</td>
<td>66.0</td>
<td>19.4</td>
<td>16.0</td>
<td>5.5</td>
<td>10.8</td>
<td>10.8</td>
</tr>
<tr>
<td>183.0</td>
<td>64.0</td>
<td>18.9</td>
<td>16.0</td>
<td>5.5</td>
<td>9.9</td>
<td>9.9</td>
</tr>
<tr>
<td>210.0</td>
<td>62.0</td>
<td>18.4</td>
<td>16.0</td>
<td>5.5</td>
<td>9.0</td>
<td>9.0</td>
</tr>
<tr>
<td>237.0</td>
<td>60.0</td>
<td>17.8</td>
<td>16.0</td>
<td>5.5</td>
<td>8.1</td>
<td>8.1</td>
</tr>
<tr>
<td>264.0</td>
<td>58.0</td>
<td>17.3</td>
<td>16.0</td>
<td>5.5</td>
<td>7.2</td>
<td>7.2</td>
</tr>
<tr>
<td>291.0</td>
<td>56.0</td>
<td>16.8</td>
<td>16.0</td>
<td>5.5</td>
<td>6.4</td>
<td>6.4</td>
</tr>
<tr>
<td>318.0</td>
<td>54.0</td>
<td>16.4</td>
<td>16.0</td>
<td>5.5</td>
<td>5.6</td>
<td>5.6</td>
</tr>
<tr>
<td>345.0</td>
<td>52.0</td>
<td>15.9</td>
<td>16.0</td>
<td>5.5</td>
<td>4.8</td>
<td>4.8</td>
</tr>
<tr>
<td>372.0</td>
<td>50.0</td>
<td>15.4</td>
<td>16.0</td>
<td>5.5</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>399.0</td>
<td>48.0</td>
<td>14.9</td>
<td>16.0</td>
<td>5.5</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>426.0</td>
<td>46.0</td>
<td>14.4</td>
<td>16.0</td>
<td>5.5</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>453.0</td>
<td>44.0</td>
<td>13.9</td>
<td>16.0</td>
<td>5.5</td>
<td>1.9</td>
<td>1.9</td>
</tr>
<tr>
<td>480.0</td>
<td>42.0</td>
<td>13.4</td>
<td>16.0</td>
<td>5.5</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>507.0</td>
<td>40.0</td>
<td>12.9</td>
<td>16.0</td>
<td>5.5</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>534.0</td>
<td>38.0</td>
<td>12.4</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>561.0</td>
<td>36.0</td>
<td>11.9</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>588.0</td>
<td>34.0</td>
<td>11.4</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>615.0</td>
<td>32.0</td>
<td>10.9</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>642.0</td>
<td>30.0</td>
<td>10.4</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>669.0</td>
<td>28.0</td>
<td>9.9</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>696.0</td>
<td>26.0</td>
<td>9.4</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>723.0</td>
<td>24.0</td>
<td>8.9</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>750.0</td>
<td>22.0</td>
<td>8.4</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>777.0</td>
<td>20.0</td>
<td>7.9</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>804.0</td>
<td>18.0</td>
<td>7.4</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>831.0</td>
<td>16.0</td>
<td>6.9</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>858.0</td>
<td>14.0</td>
<td>6.4</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>885.0</td>
<td>12.0</td>
<td>5.9</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>912.0</td>
<td>10.0</td>
<td>5.4</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>939.0</td>
<td>8.0</td>
<td>4.9</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>966.0</td>
<td>6.0</td>
<td>4.4</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>993.0</td>
<td>4.0</td>
<td>3.9</td>
<td>16.0</td>
<td>5.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>
APPENDIX E