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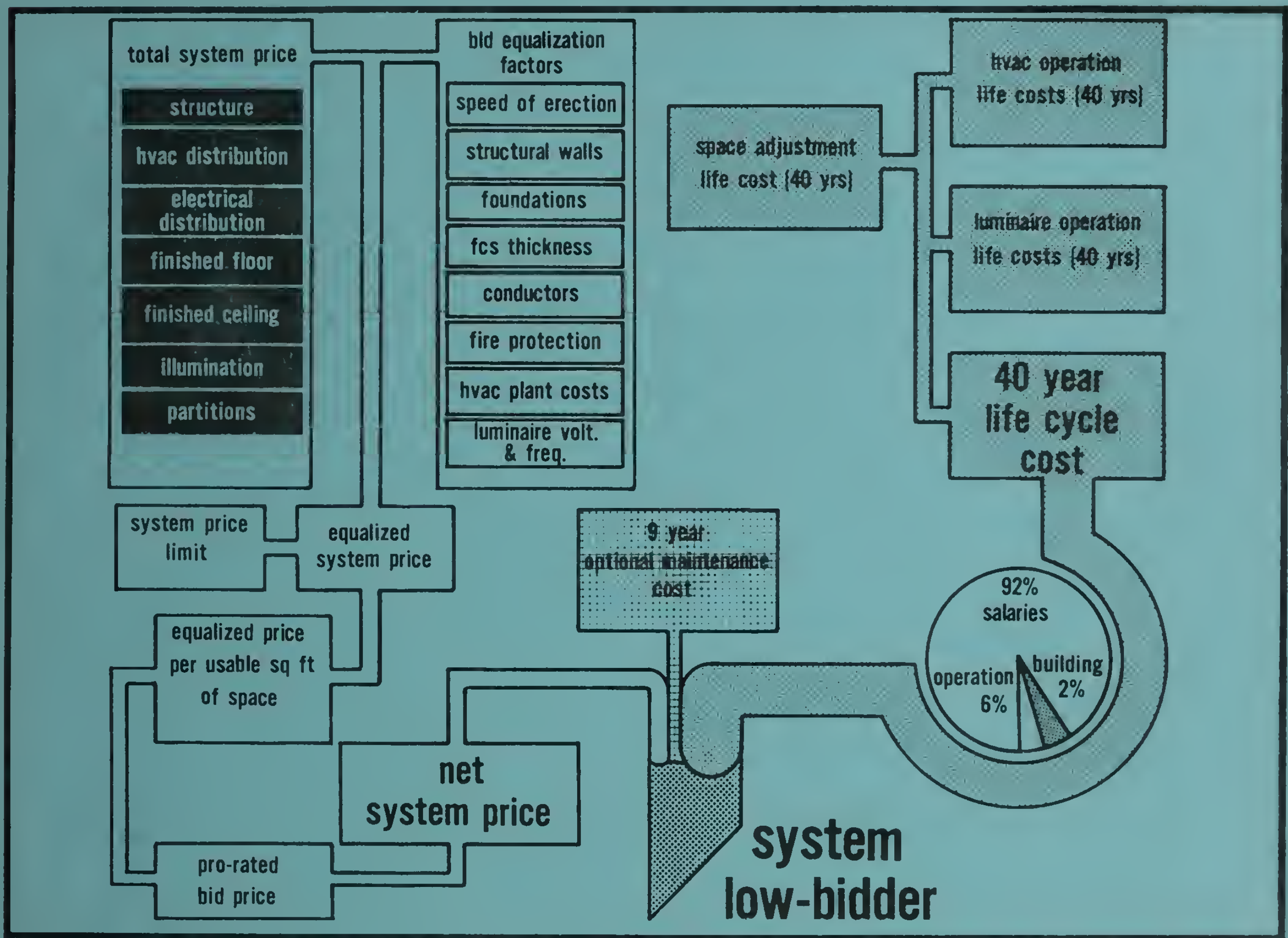
Documentation and Assessment of the GSA/PBS Building Systems Program: Final Report and Recommendations



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National Bureau of Standards
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DOCUMENTATION AND ASSESSMENT OF THE GSA/PBS BUILDING SYSTEMS PROGRAM: FINAL REPORT AND RECOMMENDATIONS

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National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Washington, DC 20234

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Sponsored by
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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, ***Secretary***
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Director***

ABSTRACT

This report assesses the General Services Administration/Public Buildings Service's (GSA/PBS) Building Systems Program (BSP) and recommends methods for furthering the program's objectives. Lighting, air movement and temperature, acoustics, and the flexibility of interior space division in the six buildings completed under the BSP are evaluated by comparing field measurements made in February-April 1982 with the performance specifications for those four attributes at the time of procurement. The wider effects of the BSP innovations on the building community are qualitatively evaluated.

By and large, GSA/PBS achieved the building performance levels it sought, but whether more conventional design and construction procurement methods would have met those levels at a lower life cost and in less time is not known, given the data available to use in the present study. Some of the specific technologies pioneered in the BSP procurements have diffused to the worldwide building community and over four million gross square feet of BSP offices are now occupied by 12,000 Federal workers. Yet, in spite of these successes, building industry participation diminished as the BSP continued. The lasting BSP contribution, however, may be in its furtherance of a novel and useful conceptualization of the stream of benefits and costs of a building project.

This report complements the project's initial report, Documentation and Assessment of the GSA/PBS Building Systems Program: Background and Research Plan (NBSIR 82-2662, February 1983), that traces the origins and conduct of the BSP from 1965 to 1980.

Key Words: building measurement; building systems; Federal buildings; field assessment; office buildings; performance specifications; post-occupancy evaluation; procurement; technical innovation.

Cover: Basis of BSP award [adopted from the Leo A. Daly (unpublished) report to PBS, "The System Approach for Building Acquisition: A Case History of the GSA/SSA Program Centers System Building Project: 1971-1975," January 1976, p. 87].

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K. R. Eberhardt	Statistical methods for sample surveys
T. Hattenburg	Illumination measurements
R. W. Marans (University of Michigan)	Perceptual/behavioral measurements; general field methods
F. F. Rudder	Acoustical measurements
S. Silberstein	Air quality measurements
F. I. Stahl	Experimental design
L. G. Porter	Statistical methods and computations
N. J. Raufaste	Coordinated the manuscript's production after author departed NBS

Several GSA/PBS staff members loaned documents and contributed advice as well as their personal recollections of the Building Systems Program (BSP). Those contributors were: J. Parker, E. Striner and C. Thomas.

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1. INTRODUCTION

The following two sections are mainly condensed from this project's initial report, Documentation and Assessment of the GSA/PBS Building Systems Program (NBSIR 83-2662, February 1983).[1]

1.1 BACKGROUND

In the early 1970s, the General Services Administration/Public Buildings Service (GSA/PBS) broadened its facilities procurement procedures to include such innovations as a "Two-step" procurement process; a wider use of "building systems" concepts; articulation and coordination of "in-system" and "out-of-system" elements; the development and use of performance specifications for building systems and subsystems; construction management for "phased" project execution; and bid evaluation based on life cycle costs.[1] These innovations -- differing from "conventional" practice and later collectively named the PBS Building Systems Program (BSP) -- were introduced in three series of building projects: Series I, Social Security Administration (SSA) Program Centers in Richmond, CA; Chicago, IL; and Philadelphia, PA; Series II, SSA Administrative Headquarters Expansions in Baltimore and Woodlawn, MD; and Series III, a multi-tenanted Federal office building in Norfolk, VA. The buildings are illustrated in figure 1 and briefly described in table 1.

Although the PBS Building Systems Program evolved continually through its lifetime (roughly, the decade of the 1970s), the program remained focused on the cost effective delivery over a structure's life cycle of "building performance which responds directly to the actual needs of building users." And, while the project's primary reference was to the shelter needs of Federal agencies, the program, from the start, anticipated the potential adoption of any or all of the system's components by other government building agencies (including States and municipalities) and by the private sector, particularly the designers and builders of owner-occupied commercial offices.

1.2 OBJECTIVES

The GSA/PBS asked the National Bureau of Standards/Center for Building Technology (NBS/CBT) to document and assess the Building Systems Program (BSP) undertaken in the 1970s.

The objectives of the larger documentation and assessment project are:

- To assess how well the distinctive objectives of the PBS Building Systems Program were met in the six facilities built to the several editions of the Performance Specification for Office Buildings.
- To recommend, for implementation by PBS, opportunities for improved building technology and building procurement practices.

1/ Available from National Technical Information Service (NTIS), Springfield, VA, 22161, for $10.00, prepaid. NTIS Order Number: PB 83-192807.

Figure 1. Exterior views of the six BSP buildings, clockwise from upper right: SSA Western Program Center, Richmond, CA; SSA Headquarters Expansion, Computer Building, Woodlawn, MD; SSA Mid-Atlantic Program Center, Philadelphia, PA; SSA Headquarters Expansion, Metro West Building, Baltimore, MD; SSA Great Lakes Program Center, Chicago, IL; Federal Building and Parking Facility, Norfolk, VA.

Table 1. Completed Building Systems Program (BSP) Projects: Summary Description

Series	Designation, Location GSA Identification Number	Size, Use and (% of BSP Total) Gross* K ft^2	Occupiable K ft^2	Office K ft^2	Population	Office Utilization Rate**	In-systems Floor	Date: Design Contract Awarded	Construction Substantially Completed	Measured
I	SSA Western Program Center 1221 Nevin Ave. Richmond, CA 94801 CA 0213ZZ	550 (13.6)	399.7 (13.7)	316.8 (13.3)	1700 (14.3)	186	5	12/14/71	7/29/75	3/14-16/83
	SSA Great Lakes Program Center 600 West Madison St. Chicago, IL 60606 IL 0233ZZ	750 (18.6)	531.8 (18.2)	445.9 (18.7)	2647 (22.3)	168	8	12/14/71	7/30/76	2/23-25/83
	SSA Mid-Atlantic Program Center 3rd and Spring Garden St. Philadelphia, PA 19123 PA 8001ZZ	550 (13.6)	390.5 (13.4)	313.8 (13.2)	2182 (18.4)	144	6	12/14/71	7/15/75	3/23-25/83
II	SSA Headquarters Expansion: Metro West Building 300 N. Green St. Baltimore, MD 21201 MD 0068ZZ	1350 (33.4)	952.4 (32.6)	728.5 (30.5)	4239 (35.7)	171	4 (North Block) 8 (Tower, 1/5 area of North Block) 5 (South Block)	4/29/74	2/1/80	2/3-7/83
	SSA Headquarters Expansion: Computer Building Security Blvd. Woodlawn, MD 21234 MD 0547AQ	590	457.8	457.8	493	—	4	4/29/74	6/1/80	2/7-9/83
III	Federal Building and Parking Facility 200 Granby Mall Norfolk, VA 23510 VA 1608ZZ	250 (6.2)	185.7 (6.4)	122.3 (5.1)	609 (5.1)	199	7	2/27/76	2/16/79	3/30-4/1/83
BSP TOTAL		4040 (100.0)	2917.9 (100.0)	2385.1 (100.0)	11870 (100.0)					

* For comparison: GSA GQ (18th and F Sts.), DC 0021ZZ is 806 K ft^2.

** Rate = Office area ÷ office population.

- To report on the advisability of implementing the Series III (prequalification) approach to building procurement.

- To identify significant building technology and procurement issues whose resolution will require further research.

The initial project report, NBSIR 83-2662, addressed three more limited objectives within the overall project. First, it focused exclusively on the attributes of the BSP procurement process and resulting environments that were explicitly different from then-current "conventional" PBS practices. In other words, elements common to all processes (conventional and BSP) are categorically excluded from the previous analysis which concentrated on the "in-system" building components. Second, NBSIR 83-2662, having identified the BSP's distinctive process and product objectives, then established methods for measuring the extent to which these objectives were achieved in the construction of the six buildings built during the BSP. Third, means for documenting the extent to which BSP process and product innovations benefited the building community at large were described. The present report details project's findings on these subjects.

During a midway review of the project's progress, GSA/PBS, acknowledging that the primary target of the project's final report was an assessment of the performance of the BSP's physical systems, asked NBS/CBT for a discussion on two additional matters:

- alternative procurement methods for Federal buildings; and

- building performance requirements needed to support future office technology.

1.3 CONCURRENT BUILDING TECHNOLOGY ASSESSMENT EFFORTS

More complete accounting of the costs over a building's life cycle has uncovered larger costs than previously had been realized,[1] and has led building owners to question the construction team's routinely passing on those costs to owners,[2] and the owner's own willingness continually to pay those costs. This last realization prompted the Business Roundtable -- the chief executive officers of 200 of the Nation's largest companies -- to sponsor the 5-year long Construction Industry Cost Effectiveness Project (CICEP).[3]

1/ "Real Estate Bull Market Over, Firm Believes," Washington Post, August 7, 1982, p. F-4.

2/ David O. Meeker, "Architects Caught in Paradox," (F. W. Dodge) Construction News, April 22, 1983, p. 7.

3/ "Managing the Business Roundtable Multimillion-dollar Effort to Guide Construction Toward Improved Cost Effectiveness," Engineering News Record, February 10, 1983, p. 52.

The President's Private Sector Survey on Cost Control (PPSSCC)--working 70 staff months--identified 23 specific recommendations that, when fully implemented, could result in 3-year total cost savings of $5.1 billion and firstyear cost savings of $1.6 billion, all without reducing the "benefits derived from Federal construction programs [that] are important to our society."[1]

While the CICEP and PPSSCC addressed the costs of erecting new facilities, others have analyzed the sizable costs of keeping such a facility in good condition through its operating life. The emergence of "Facilities Management" as a professional specialty, complete with degree and non-degree granting educational institutions and a professional literature of its own testifies to seriousness of keeping buildings functioning effectively.[2]

How effectively a building performs its function, however, is not always obvious. There are several reasons for this, some of them conceptual and others more narrowly technical. Buildings perform many functions simultaneously -- public buildings, for instance, are expected to serve symbolic as well as utilitarian purposes. This report deals exclusively with the more explicitly utilitarian purposes of a series of Federal office buildings and, of these, an even smaller number of the more tractable aspects of physical performance. But, in even this restricted area, problems remain. The specialty of "building diagnostics" is emerging to address these problems.

A committee of the National Academy of Sciences - National Academy of Engineering Advisory Board on the Built Environment (ABBE) recently defined building diagnostics as: the use of modern methods of measurement and interpretation to assess the performance capability of a building. Building diagnostics is, quoting ABBE again, "in its infancy."[3] The press serving the building design and construction professions is providing a flow of books and articles

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1/ May 17, 1983, Letter transmitting the Task Force Draft Report on Federal Construction Management, to the PPSSCC Chairman.

2/ The status of professional education is reviewed in Pat Lyons, "Facilities Education: Colleges Form Facilities Majors to Meet Demand for Paycheck-Ready Graduates, Facilities Design and Management, February/March, 1982, p. 27.

3/ ABBE, A Report from the Workshop on Building Diagnostics, March 1983, (Washington National Academy Press, 1983), p. 1.

describing candidate diagnostic methods[1] and are compiling inventories of tools.[2]

In addition, the American Society for Testing and Materials (ASTM), Committee E6 on Performance of Building Construction, Subcommittee E6.24 on Building Preservation and Rehabilitation Technology, is developing a series of three manuals of procedures for improving building performance. These manuals will address improvements in the performance of components as well as overall building performance. Assessment of the performance of buildings in use, the object of the present study, is often the starting point for a performance improvement program. Consequently, the results of the current GSA/NBS cooperative research program, including the present report, will be made available to the cognizant ASTM technical committees. That is one reason for the detailed presentation of data collection methods in section 2.

1.4 ORGANIZATION OF THIS REPORT

This report is in four sections and two appendices: an Introduction, recapitulating the project's initial report; Data Collection, describing the way measurements of physical performance during service conditions were made; the Results section reporting in summary form the data collected at the BSP sites; a Discussion of what the results mean, both scientifically, (that is in terms of significant statistical relations, useful generalizations, and conclusions can be drawn and with what evidence), and in terms of the several project and BSP objectives outlined in this report's Introduction. The implications of this research for GSA/PBS are developed in the Recommendations section that concludes the main report. The discussion of alternative procurement methods for Federal buildings and of building performance requirements needed to sustain future office technology are also included in that section.

1/ Lerchen, F. et al., Selected Methods for Condition Assessment of Structural, HVAC, Plumbing and Electrical Systems in Existing Buildings, NBSIR 80-2171, National Bureau of Standards, Washington, DC, November 1980.

Thomas Vonier reviewed several methods and devices in the Technics section of the March 1982, Professional Architecture, pp. 143-149.

2/ The flow of products is sufficient to warrant distribution of new product announcements. One such series is the New Products Bulletin of the Preservation Resources Group in Springfield, VA. The winter 1982 number featured digital moisture detectors, temperature and humidity circular chart recorders, optical range finders, etc.

2. DATA COLLECTION

2.1 INTRODUCTION

Chapter 5 and appendix B of NBSIR 83-2662 describes NBS/CBT's derivation of the field methods used to assess in-service performance of the six BPS buildings. The present chapter describes in further detail the exercise of these methods in the field and lists the specific design values each method attempted to measure. Methods for collecting data on the effects of the BSP on the wider building community, data not collected on the BSP sites, were treated fully in chapter 6 in NBSIR 83-2662, and are not described further in this section except to list the corresponding experts in section 2.7.

One of the purposes of this report is to facilitate other researchers' use of these methods; consequently, the last section of this chapter is organized as a narrative description of a typical site visit. The description is sufficiently detailed to permit others to replicate the NBS/CBT work. Another reason for the detail is to reveal how variable local conditions may be and how much more complicated field studies can be when compared with the controlled conditions of laboratory research.

The performance evaluation methods NBS/CBT used were adapted from those stipulated in the several editions of the Peach Book.[1] The Peach Book specified tests intended to aid preprocurement decisionmaking, not to evaluate in-service performance; an earlier report, NBSIR 83-2662, gives the rationale for adapting rather than replicating the Peach Book methods. Table 2 of the present report lists the specific methods NBS/CBT used in its field work and traces the origins of methods chosen to enhance or replace those required by the Peach Book; a more complete narrative explanation of table 2 follows, including the design values specified in the several editions of the Peach Book.

2.2 AIR MOVEMENT AND TEMPERATURE

2.2.1 Peach Book Required Values and Procurement Test Methods

The current project examined two aspects only of the indoor thermal environment's performance: air movement and temperature. The several editions of the Peach Book carried clear and quantitative criteria. But the precise numbers were different for the Peach Book, first edition, revised (PB:IR) and the later two editions. PB:IR stipulated an indoor design condition for 24 hrs/day, 365 days/year at 75°F DB (dry bulb) minimum for November through March and 75° DB maximum from April through October.[2] These temperatures, anywhere in a conditioned zone, were allowed to swing ± 5°F from the value at the thermostat. Conditioned air could move no less than 20 FPM (0.10 m/s) and no more

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1/ The Performance Specification for Office Buildings became familiarly known as the "Peach Book" because of the color of its original cover.

2/ PB:IR, p. F-37. Recall that PB:IR was issued almost two years before 1973 Arab Oil Embargo.

Table 2. Brief Comparison of Peach Book and NBS Methods Used to Measure Selected Attributes

Attribute	Methods Required by Peach Book	Methods and Equipment Actually Used	Reference
Air Movement, Temperature	Air Diffusion Council Equipment Test Code 1062 (R4)	Peach Book; ASHRAE 55; Datametrics Air Flow Meter	Peach Book Referenced Standards; ASHRAE 55
Illumination	5 Calculations 1 Field Test	Photo-Research Photometer; SH&G Contrast/ ESI Meter	IES Lighting Handbook; DeLaney, et al.[1]; Goodbar[2]
Acoustics	ASTM E336-6T ISO R-140 PBS C.1 (Subjective) C.2 (Objective)	B&K Sound Level Meter	NBS Developed Procedure
Planning	Calculations	Archival Data in Building Records	Webb et al.[3]

1/ W. B. Delaney, et al., "Using the ESI Meter in Lighting Applications," Journal of the IES, vol. 8, no. 4, (July 1979), pp. 229-234.

2/ Isaac Goodbar, "The Application of the ESI System to Office Lighting, Lighting Design and Applicaton, (November 1982), pp. 29 ff.

3/ Eugene J. Webb, et al., Unobtrusive Measures: Non-reactive Research in the Social Sciences, (Chicago: Rand, McNally, 1966). Particularly Chapters 3 and 4.

than 50 FPM (0.25 m/s)[1] and movement was to be measured using Air Diffusion Council's Equipment Test Code 1062 R2.[2]

Peach Books:2 and 3 retained the air movement and temperature variation values[3] but stipulated design temperature differently: 73 to 77°F DB when mean radiant temperature approximated the dry bulb value.[4] The measurement method remained the same throughout.

But all the Peach Book temperature specifications were "overridden", in effect, when the GSA Administrator amended the Federal Property Management Regulations (FPMR's) in November 1974, February 1976, and October 1977 as part of a governmentwide effort to conserve energy.[5] Specifically, agencies were directed to maintain 65° to 68°F temperatures during working hours during the seasonably cold months. The amendments permitted higher temperatures so long as no further energy was used in maintaining the higher temperatures (the amendments acknowledged, for instance, the likelihood that gain from direct sunlight into perimeter areas of buildings might produce higher winter temperatures and that the heat generated by equipment and workers' bodies might drive up the temperature of the interior zones of buildings. But the amendments specifically prohibit the use of cooling energy to achieve the specified temperatures).[6]

2.2.2 NBS/CBT Field Test Methods

The Air Diffusion Council method stipulated by the Peach Book calls for the Anemotherm Air Meter hot-wire anemometer. The NBS/CBT team's pilot test at the Metro West Building in Baltimore[7] used the Anemotherm and the lighter-weight Datametrics 100 VT Airflow Meter for the first few measurements, both gave effectively the same results. The team then switched to the Datametrics instrument exclusively because its quicker response time and convenient size were more suitable for project's needs.

NBS/CBT supplemented the Air Diffusion Council method with ASHRAE 55-1981 Thermal Environmental Condition's for Human Occupancy whose table 5 specifies

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1/ PB:IR, p. G-63.

2/ PB:IR, p. G-62.

3/ PB:2, p. E-33.

4/ PB:2, p. G-42.

5/ FPMR Amendments D-48 (February 1976) and D-60 (October 1973) issued by GSA to heads of Federal agencies.

6/ FPMR D-48, p. 2016.

7/ Described in appendix B of NBSIR 83-2662, p. B-6 and B-7.

exact locations for making comfort measurements. ASHRAE 55-1981 requires that "air temperature and air movement shall be measured at the 0.1, 0.6, and 1.1 m (4, 24, and 43 in) level for sedentary occupants...."

The Datametrics instrument also measured temperature and for this purpose was calibrated against a mercury in glass thermometer at frequent intervals to assure accuracy.

2.3 ILLUMINATION

2.3.1 Peach Book Required Values and Procurement Test Methods

The greatest change in the specification of lighting performance during the course of the BSP was the shift from specifying luminance of sources in terms of foot-lamberts conforming to the then-current "scissors curve criteria" of the Illuminating Engineering Society[1] to a specification of illuminance in terms of Equivalent Sphere Illumination (ESI).[2] Peach Book:2[3] and Peach Book: 3[4] specified an average illuminance of 60 ESI footcandles in three orientations, with a minimum of 30 ESI footcandles at any single one of the three orientations. Peach Book:1R, on the other hand, specified illuminance in "raw" footcandles, the amount of illuminance keyed to the size of the "room".[5]

The FPMR amendments cited in section 2.2.1 also affected lighting practices in the Peach Book buildings and did so in two ways. First, heads of Federal agencies were encouraged to introduce "nonuniform lighting standards" (the Peach Book, in contrast, specified uniformity) into existing installations and the removal of "excess lamps and fixtures" was expressly recommended as a means of achieving these new requirements. Second, overhead lighting at work stations was reduced to 50 (raw) footcandles. This was a considerable reduction from the 60 ESI footcandles of PB:2 and PB:3.

All three Peach Books relied heavily on calculations for determining the lighting subsystem's conformance with the stated criteria. In PB:2, for instance, only the criterion for uniformity was measurable in the field; the five remaining tests were calculations.

1/ IES Lighting Handbook, 4th Edition, (New York: IES, 1966) pp. 2-20 to 2-21.

2/ IES Lighting Handbook, 5th Edition, (New York: IES, 1972) passim.

3/ PB:2, pp. G-86, G-88.

4/ PB:3, pp. E-81, E-83.

5/ PB:IR, p. G-135.

2.3.2 NBS/CBT Field Test Methods

Advances in theory, methods, and instrumentation since the development of the Peach Books permit physical measurement of ESI values in the field.[1] These devices generate numerical data that represent a visual task's reflectance characteristics -- their bidirectional reflectance distribution functions (BRDF's) -- from which ESI is then calculated.[2]

NBS/CBT purchased a Series 1000 Contrast ESI Meter (calibrated for a "Number 2 pencil on white paper" visual task) and associated software from Smith, Hynchman, and Grylls. The Meter was used in conjunction with a Photo-Resarch Spectra brand photometer (Model FC-200) whose probe was inserted in the Meter's base at 30 in. (760 mm) above the floor, the reference plane for all Peach Book lighting measurements. Pursuant to the IES recommended practices, illumination measurements were made at night to control the variation introduced by highly variable natural daylight.

The luminance of visual tasks are particular to viewing direction and those directions are specified exactly in PB:2 and PB:3 (PB:1 sought raw illuminance only). The azimuthal orientation of the Meter was matched with those specified in the Peach Books and average illuminance were calculated at NBS based on readings taken in the six BSP buildings. To assure accuracy, the photometer was rezeroed at frequent intervals during field measurement and was calibrated at NBS after each field visit.

2.4 ACOUSTICS

2.4.1 Peach Book Required Values and Procurement Test Methods

The specification of acoustical performance changed radically shortly after the initial Peach Book (PB:1) was issued in January 1971. GSA/PBS, anticipating the growing use of open-plan approach to office layout, commissioned Geiger-Hamme Laboratories to develop tests for determining whether candidate architectural designs provided speech privacy sufficient for the conduct of office functions. The results were the Speech Privacy Potential (SPP) tests that consider the acoustical effects ceilings (including lights and air diffusers), background masking systems, sound screens, and other vertical surfaces all acting simultaneously.[3] Test facilities are identical for an objective and

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1/ J. McNelis, JIES, and I. Goodbar, LD&A, cited fully in notes to table 2.

2/ IES Lighting Handbook, 1981 Reference Volume, (New York: IESNA, 1981), pp. 4-8 to 4-9.

3/ These test specifications are known familiarly as PBS-C.1 and PBS-C.2, and more formally as, Method for the Direct Measurement of Speech Privacy Potential (SPP) Based on Subjective Judgements and Method for the Sufficient Verification of Speech Privacy Potential (SPP) Based on Objective Measurement, Including Methods for the Rating of Functional Interzone Attenuation and NC-Background respectively.

subjective measure of SPP. Systems that fail the objective tests may still qualify if they meet the subjective tests.

GSA/PBS commissioned these methods because conventional tests proved unreliable predictors of the acoustical performance of open plan offices.[1]

This new method was incorporated by reference in the September 1971 revisions (PB:IR) and all subsequent editions of the Peach Book.[2] The noise criteria (NC) stipulated in the Peach Book were: for PB:IR, Sound Pressure Level (SPL) < NC 35 when all systems are operating;[3] for PB:2, SPL < NC 35 when all systems are operating except background sound;[4] for PB:2, SPL < NC 35 when all subsystems (presumably including background sound; the Peach Book is ambiguous on this point) are operating[5].

2.4.2 NBS/CBT Field Test Methods

SPP is one of the technical innovations introduced in the course of BSP and the extent of its diffusion will be discussed further in section 3. One of the factors affecting SPP's general utility in the wider building community is its complexity and the resources required to administer the subjective and objective portions of the test. This complexity militated against the use of SPP in the assessments made in the current project. GSA/PBS staff advised NBS/CBT that a rigorous SPP evaluation would reqire 8 hours per test, far in excess of what the project's budget would allow. Moreover, SPP incorporates a subjective component and requires testing while the subject spaces are unoccupied and office equipment idle. But since the present project addressed building assessments in "real time" and under service conditions, NBS devised a method for measuring ambient noise in the BSP. NBS estimated NC ratings using A-weighted sound level data including office-generated noise, the in-service condition of the six BSP buildings. The approximating technique was devised as follows:

> In the absence of the generated noise (a situation occurring only in the "compartment" offices"[6]) the A-weighted sound level of

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1/ David A. Harris, et al., Planning and Designing the Office Environment (New York: Van Nostrand-Reinhold, 1981), p. 76. The tests were ASTM E-336 (Noise Isolation Class), ASTM C-423 (Noise Reduction Coefficient), and ASTM E-90 (Sound Transmission Class).

2/ Further documentation is in NBSIR 83-2662, section B.5.2.

3/ PB:IR, pp. G-8 and G-9. Specific values listed at p. G-71.

4/ PB:2, p. G-8. Specific values listed at pp. G-8 and G-9.

5/ PB:3, p. E-10 for method and specific values.

6/ The three types of interior space arrangement, compartment, open plan, and pool are described in section B.3.4 of NBSIR 83-2662.

mechanical equipment noise, $(L_A)_{NC}$, related to the NC rating by the approximation.[1]

$$(L_A)_{NC} \approx NC + 7, \text{ dBA}$$

In the presence of office-generated noise of level, L_{office}, one obtains the approximation:[2]

$$L_{office} - NC \approx 7 + 10\log\{0.2 \cdot 10^{(L_{Total} - NC)/10} - 1\}, \text{ dBA.}$$

This approximate relationship may be used to judge the relative contribution of office-generated noise to the total measured A-weighted sound level, L_{Total}, and the specified NC rating.

For $L_{Total} - NC \geq 16$ to 18 dBA, the measurement (L_{Total}) is predominantly office-generated noise. For $L_{Total} - NC$ between 10 to 16 dBA, office-generated noise is greater than the mechanical equipment noise (as characterized by the approximate A-weighted level/NC relationship). For $L_{Total} - NC$ less than 10 dBA, the mechanical equipment noise is the predominant contribution to the total noise environment, and one may estimate the NC rating using:

$$NC \approx L_{Total} - 7$$

The A-weighted ambient sound level at the BSP sites was measured with a B+K Sound Level Meter on a 360° traverse for 1 minute while the spaces were occupied. Since the objective of the assessment was to measure conditions as they actually occur, the background sound masking system was left "as is," during the field tests: if "off," it remained off; if "on," on. The meter was electronically and acoustically calibrated after every tenth reading.

2.5 PLANNING (FLEXIBILITY OF INTERIOR SPACE DIVISION)

2.5.1 Peach Book Required Values and Procurement Test Methods

BSP procurements were awarded among competing vendors on a basis that reflected the lowest cost to the PBS of rearranging interior spaces after the buildings procured were occupied.

Peach Book:IR described a prototype planning change in the form of a "Phase I and Phase III" floor plan (including 70 lineal feet of floor to ceiling partitions and two single-leaf doors) and a "Phase II" floor plan (to which

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1/ Leo L. Beranek (ed.), Noise and Vibration Control, (New York: McGraw-Hill, 1971), p. 591.

2/ Adapted from Beranek by NBS Acoustical Engineer, Fred Rudder.

30 lineal feet and two more single-leaf doors were added[1]). Competing vendors were directed to estimate costs of changing their prototype structures through one cycle of Phases I, II, and II changes per year over the 40 year life of each BSP building.[2]

Peach Books:2 and 3 were more complete in the scopes of their performance criteria. First, PB:2 and PB:3 limited any damage inflicted on the flexible system in the course of the change to less than 5 percent of the original cost of the system.[3] Second, the interior space division system was required to accommodate the installation within 30 minutes of luminaire control switching associated with the change.[4] Both PB:2 and PB:3 provided calculation methods "before" and "after" configurations analogous to the Phases I, II, and III of PB:IR.[5]

But the most substantial change in specifying planning flexibility came in substituting for PB:IR's single prototype planning change per year a schedule of expected rates of change for each subsystem in the BSP buildings, and the fractions of floor areas over which such changes were expected to be affected were also listed. The areas and rates of change are listed in table 3.

2.5.2 NBS/CBT Field Test Methods

NBS/CBT's proposed use of archival records to gauge the adequacy and appropriateness of the space division performance criteria is fully discussed in NBSIR 83-2662.[6] In summary, actual changes to the several subsystems in a representative year were to be enumerated by analyzing the Reimburseable Work Authorizations (RWA's) maintained in the GSA/PBS field offices serving the six BSP buildings.

2.6 FIELD PROCEDURE

2.6.1 Arrangements Preceding Field Visits

The GSA/PBS Assistant Commissioner for Design and Construction wrote to the Regional Administrators (and Directors of their Buildings Management Divisions) where the six BSP sites were located to advise them of the purpose of the

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1/ PB:IR, Amendment N.4, p. F-39.

2/ PB:IR, p. F-51.

3/ PB:2, p. G-176, PB:3, p. E-186.

4/ PB:2, p. G-177; this provision was dropped in PB:3.

5/ PB:2, Amendment 6, February 1975, pp. 1-11; PB:3, Amendment 1, April 1976, pp. G-5.1 to G-5.12.

6/ At table 5.2, p. 31, see pp. B-7 through B-9 for a discussion of the advantages and disadvantages of this method.

Table 3. Rate of Change and Area of Change Factors for Planned Change of BSP Interiors*

SUBSYSTEM	ANNUAL RATE OF CHANGE		AREA PER 1000 SQ. FT.
	PB:2[1]	PB:3[2]	PB:3
Structure (sprinkler)	0.035	0.035	25%
HVAC	0.035	0.035	25%
Electrical Distribution			
Office Power	0.11	1.2	85%
Telephone	0.18	1.32	85%
Signal	0.15	0.375	85%
Luminaire Switching	0.035	0.035	25%
Luminaires	0.03	0.03	100%
Finished Floor	0.10	0.10	85%
Finished Ceiling	0.10	included with other subsystems	
Space Dividers			
Partitions	0.07	0.07	25%
Screens	0.02	0.15	75%

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* PB:1 specified planned change in a manner incommensurate with the specifications in the later two editions.

1/ Amendment 8, September 1975, p. 12.

2/ Amendment 1, April 1976, p. G-5.13.

documentation and assessment project and explained how its results would be useful to GSA/PBS. The Assistant Commissioner's letter authorized the NBS/CBT researcher to contact directly the cognizant building manager.

This initial step proved helpful from several points of view, expediting the field work. The regional offices alerted in advance the building managers who, assured by their own management of the project's priority, provided excellent cooperation when later contacted by NBS.

2.6.2 Preliminary Arrangements at the Site

The building manager cooperated by: 1) assembling architectural drawings and other documents describing the building's physical systems and operating protocols; and 2) providing physically secure work and equipment storage space. This served the NBS/CBT field worker as an operations base; 3) assisting in the researcher's review of past Reimburseable Work Authorizations and, perhaps most importantly; 4) arranging for security clearances for entering and for remaining in the BSP buildings before and after regular work hours. Entry and use of the BSP buildings is restricted, particularly in the Social Security Administration's operating areas where earnings data and other personal information is maintained.

2.6.3 Site Reconnaissance and Sampling

Upon arrival and after introductions (sometimes to a representative of the tenant agency), the NBS researcher established an operations base in the building manager's or engineer's office.

Equipped with reduced-sized drawings (in which every structural bay was assigned a unique number in a linear array of natural numbers), colored pencils, a tape measure, and pass keys, the NBS researcher toured the entire in-system portion of the building. All bays were assigned (and designated by color code) to one of the three categories depending on their spatial arrangement:

1) compartment offices -- spaces with rigid, fixed floor to ceiling partitions;
2) screen offices[1] -- spaces subdivided by columns and by modular, moveable barriers ranging in height from 5 ft 0 in. to 6 ft 6 in.; and
3) pool offices -- in which there were no vertical barriers above desk height except the structural columns.

This project's initial report described the rationale for sampling and discussed both the uses of stratification and a method of randomization.[2] The building

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1/ The project's initial report referred to this category as "open plan areas." The present terminology, "screen office," introduced to reduce possible confusion between it and "pool" or undifferentiated space of categories three.

2/ NBSIR 83-2662, appendix B.1 to B.4, pp. B1 to B5.

spaces were assigned to the cells defined in table 4. This was the factorial matrix for subsequent statistical analysis.

Table 4. Subdivisions of the BSP Environments

Location / Spatial Arrangement	Interior	Perimeter
Compartment		
Screen		
Pool		

This project's statistical consultant[1] recommended that, given the range of performance values expected at the BSP sites, the accuracies desired in the final estimates (that is, the acceptable statistical uncertainty) and the sizes of the buildings over which that range was expected to occur, 30 observation sites per building would be a suitable sample. Moreover, computational efficiency suggests that all cells contain an equal number of observations; this greatly facilitates drawing cell-to-cell comparisons.[2]

When the onsite walkthrough was completed, the researcher, having previously assigned each bay a unique number, obtained random numbers (drawn from a random number table) that corresponded to those bays that became the random sample of building spaces. Random numbers were drawn until all six cells of table 4 were filled, satisfying the stratification requirement.

This method indicated exactly which bays in the buildings were to be taken for the sample. Randomness meant that every in-system part of the BSP building had an equal chance of being selected as part of the sample; stratifying the sample meant that comparisons could be drawn between significant categories of space within the BSP buildings.

1/ All project technical consultants are listed in Acknowledgements Section.

2/ If the object of the study were to represent reality, then the number of observations per cell should be proportional to the numbers of bays of each category in the actual building. Since the project assessed a program and not single buildings, spaces were assigned to cells to assure uniform coverage. Analysts seeking to describe reality can, however, weight the values in cells proportionately to reflect the actual situation in any given building. See this issue in drains in Mary G. Natrella, NBS Handbook 91: Experimental Statistics, Washington, DC, USGPO, 1963, chapter 11.

2.6.4 Field Measurements

Instruments for measuring air movement and temperature, illumination and ambient sound, pencils, measuring tape, and calibration devices fit into a single 18 in. x 24 in. x 9 in. foam-lined, lockable case mounted on a wheeled carrier; all are illustrated in figure 2. Figure 3 is the Field Data Collection Sheet that served as a procedure manual for the field measurements. Values for Bay Number, and designations for Location and Space Type, were inserted at the outset, when the stratified random sample was drawn. The researcher then proceeded to the selected bays with the needed equipment.

At the center of each preselected bay, the instruments were set up and data recorded in a manner illustrated in figures 4 and 5, respectively, the air movement and temperature readings and the lighting measurement. Pursuant to recommended practices of the Illuminating Engineering Society, the lighting measurement was actually made at night, thus controlling the high variable illumination contribution from natural daylight. Consequently, two trips were made to each preselected bay. All other measurements were made while the spaces were occupied by workers performing their customary duties and all environmental conditioning, including background sound, were operating normally.

2.7 DATA ON THE WIDER EFFECTS OF THE BSP

NBSIR 83-2662 described how information on the effects of the BSP on the wider building community was drawn from discussions with participants and knowledgeable observers, including unsuccessful bidders, of the Peach Book procurements. The discussions focused on the materials comprising section 6 of NBSIR 83-2662, a listing of process and product innovations and definitions of the several categories of project success or failure. The listing is reproduced as table 5 and the roster of discussants is table 6.

Figure 2. Portable intruments for measuring: 1) air movement and temperature; 2) illumination; and 3) ambient sound pressure

BSP DOCUMENTATION AND ASSESSMENT PROJECT

NBS/CBT FIELD DATA COLLECTION SHEET (Revised)

Building: ______________ Date: ________ Reporter: ______________

Time: ________

Floor: __________ Bay No.: ___-____ Location: ________ Interior

Occupying Unit: ______________________ ________ Perimeter, if yes, then

______________________________ Orientation: ____ N

____ E

Space Type: ____ Compartment Size: _____ x _____ ____ W

____ Open Plan ____ S

____ Pool

Sky: ________ Clear

Dominant Worker Orientation: ____ N ____ E ____ W ____ S ________ P/C

________ Overcast

________ Twilight

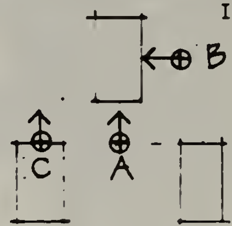
Work Stations: No. Vacant ________ ________ Night

No. Occupied ________

Ambient Sound Level, One Minute dB(A)			Ambient Air Velocity m/s (above floor)			Ambient Air Temperature °C (above floor)		
Max	Min	ECT	0.1 4	0.6 24	1.1 m 43 in	0.1 4	0.6 24	1.1 m 43 in

Illuminance (lux)

30 in above floor



Luminaires: ______ Total ______ Malf.

	A	B	C
Raw			
Rb			
Rd			

Audible Footfalls: ____ Y

____ N

HVAC Noise Obvious: ____ Y

____ N

Space Dividers Height ______ ______ ______ ______

Lineal ft ______ ______ ______ ______

Equipment Audible? ________ dB(A) at ________ ft

________ dB(C)

Floor: ____ Carpet

____ Resilient

____ Other

Adaptations by Mgmt:

Ceiling Background Audible: ____ Y

____ N

by Worker:

Actual: ____ dB(A)

Figure 3. NBS/CBT field data collection sheet BSP documentation and assessment project (revised)

Figure 4. Measuring air movements and temperature at heights above floor prescribed by ASHRAE Standard 55

Figure 5. Measuring illuminance at a reference plane 30 in (760 mm) above floor. (Meter's lead wire long enough to prevent reader's shadowing the probe itself)

Table 5. Outcomes of BSP Process and Product Innovations

	Information Success*		Application Success*			Diffusion Success*		
	Yes	No	High	Medium	Low	Signif.	Some	None
PROCESS INNOVATIONS								
Integrated Research and Design Teams								
Life Cycle Costing Economic Analysis								
Speech Privacy Potential Acoustical Design								
Prequalification for Public Procurement								
PRODUCT INNOVATIONS								
Integral HVAC-luminaire-fire protection package								
Structure								
HVAC								
Electrical Distribution								
Luminaires								
Finished Floor								
Finished Ceiling								
Space Dividers								

* Terms defined in section 6.3 of NBSIR 83-2662.

Table 6. Roster of Discussants

Name	Relation to BSP	Current Affiliation (If Different from BSP relation)
David Hattis	NBS Researcher, Coauthor of PB:1	Independent Consultant, Building Technology, Inc.
Robert Ramsey	Project Architect with Leo A. Daly, Co., Systems Consultant/Executive AE on all three BSP procurements	Senior Vice-President, Leo A. Daly, Co.
Gershon Meckler	Mechanical Engineering Consultant to joint venture that won Series I procurement	Partner, Haines Lundberg Whaeler
Peter Kastl	Project Architect with The Ehrenkrantz Group, System Consultant on Series II and Series III procurements	Member, The Ehrenkratz Group
Clifford Thomas	GSA Project Manager on Series I and Series II procurements	GSA Acting Deputy Commissioner for Design and Construction
Robert Blake	An early NBS conceptualizer of BSP. Head of HHS Facilities Engineering Group (tenant for five of six BSP buildings)	Independent Consultant, (retired from government service)
Sheldon Steiner	Engineer, Flock and Kurtz unsuccessful bidder on Series I and Series II procurements	Partner, Flock and Kurtz
Edison Price	Designer of innovative luminaire used in Series II and Series III buildings	Lighting designer and manufacturer marketing worldwide the luminaire initially developed for BSP
John B. Tibbets	Owens-Corning Fiberglas employee, assigned as manager of joint venture (Owens-Corning Fiberglas/ Wolff and Munier/Westinghouse/U.S. Steel/E. C. Enrst) that won Series I and II BSP procurement	President, Tibbets, Inc. manufacturer of office furniture components developed initially for BSP procurements by Owens-Corning Fiberglas
David Miller	Executive with Hauserman, Co., unsuccessful bidder on BSP procurement	Independent building products marketing consultants
Robertson Ward	Consultant to NBS at conceptualization stage of BSP	Architect/Inventor

3. RESULTS

3.1 INTRODUCTION

This section reports the field assessment of the selected performance attributes in the six BSP buildings during the winter of 1983. The exact dates of the measurements at each building are listed in table 1; the quantities measured, the methods used and the origins of those methods are summarized in table 2.1 and explained more fully in section 2. The actual, measured performance is compared in this section with the levels specified in the several editions of the Peach Book. Measurements are presented in both SI (metric) and U.S. customary units.

Standard statistical tests for the homogeneity of variance between locations (perimeter and interior zones) and spatial arrangements (compartment, screen and pool offices) among and between the BSP buildings were performed.[1] Where the overall analysis of variance was significant, then the mean differences between groups were further evaluated using Scheffe's or Duncan's and are the basis for the following discussion. Statistically significant parameter differences ($p \leq 0.05$) occurred almost everywhere, with differences between buildings (and series) usually larger than differences among locations and spatial arrangements within buildings.

3.2 AIR MOVEMENT

Figure 6 reveals that air movement performance failed to meet specific velocities in almost all cases. The exceptions were the regions nearest the floor, the effect expected from principles of physics. But air movement performance did show some slight improvement from one series of building procurements.

1/ Data collection in the field always includes the hazard of missed or incomplete observations. Anticipating this, a decision was made at the outset never to insert artificial or statisically-created measurements for using field data. Rather, in these few cases, categories where collapsed and alternative analyses employed. This is a very conservative approach but worth the additional effort in the confidence that can be placed in the results.

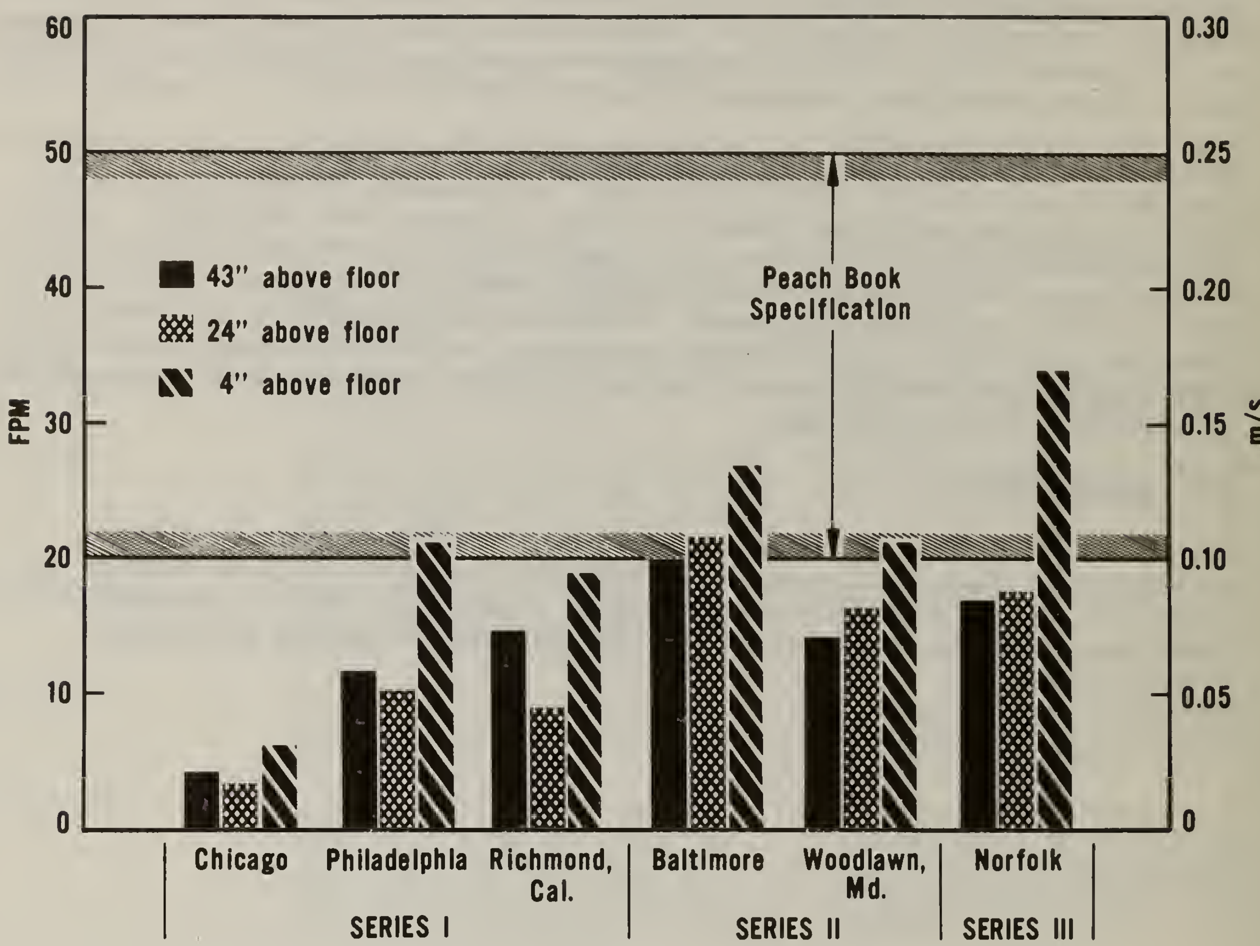


Figure 6. Specified and measured air movement in six BSP buildings, summary

Air movement in the perimeter zones showed little variation from movement in the interior portions of the BSP buildings at 100 mm (4 in) and 960 mm (24 in) elevations above the floor. This is presented in figures 7 and 9. The exception is the Woodlawn, MD SSA Headquarters Computer Building whose interior zones are entirely dedicated to housing central processing units, tape and disc drives, tape storage vaults, and printing facilities. These spaces are intended for only intermittent human occupancy. Ironically, the SSA machine areas are closer to the performance specified in the Peach Book than are the spaces intended for human use.

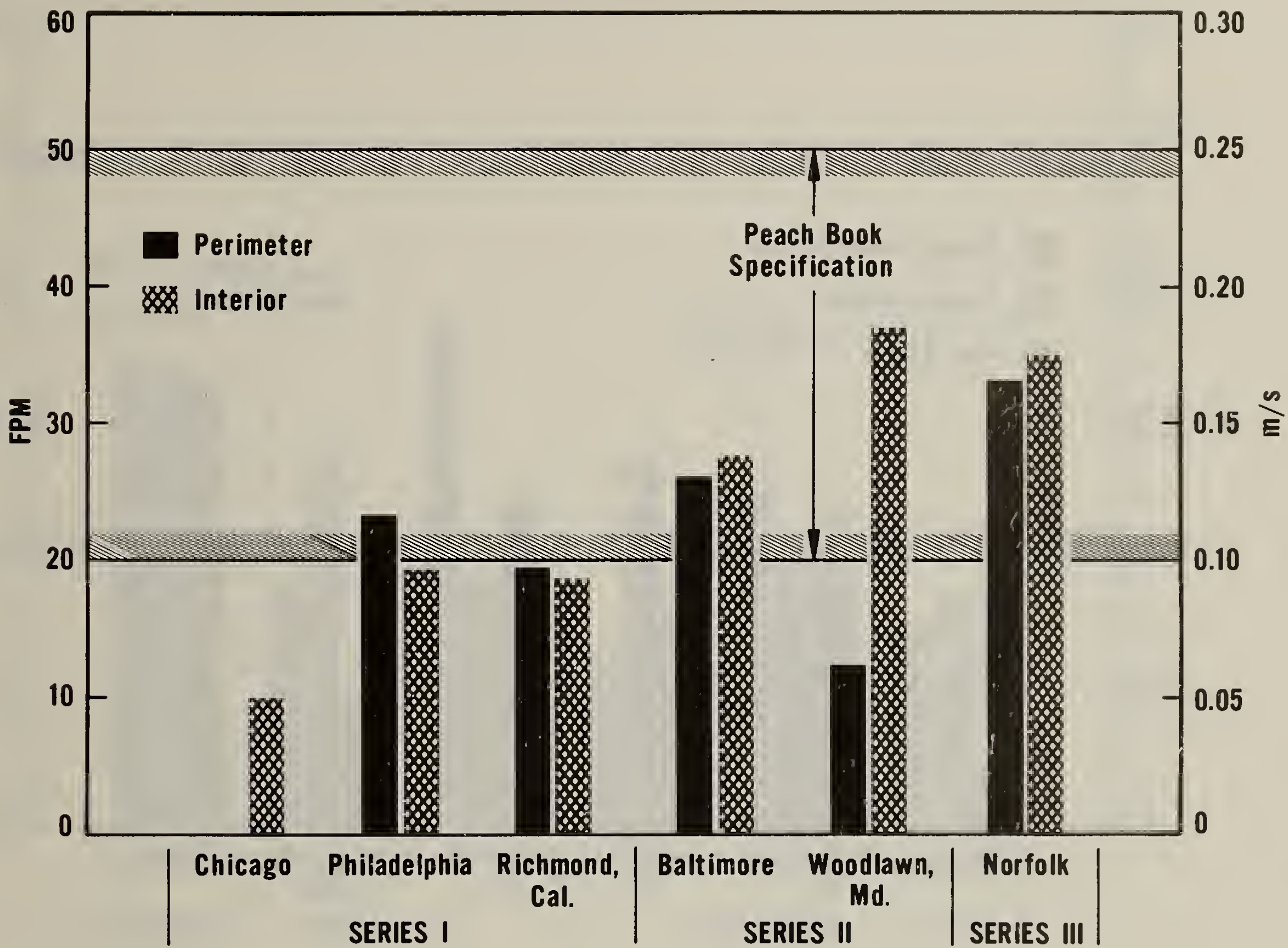


Figure 7. Specified and measured air movement at 4" (100 mm) above floor, perimeter vs. interior locations

Perimeter zone air movement differed markedly from interior zone movement at the 1100 mm (43 in) level, but neither zone performed well within the range specified by the Peach Books. This is illustrated in figure 11.

Figures 8, 10, and 12 reveal that whether an office space was a pool, screen, or compartment arrangement bore no systematic relation to the air movement within that office: the uniformity of the air handling system apparently overrode the variations in spatial subdivision. Nevertheless, the overriding

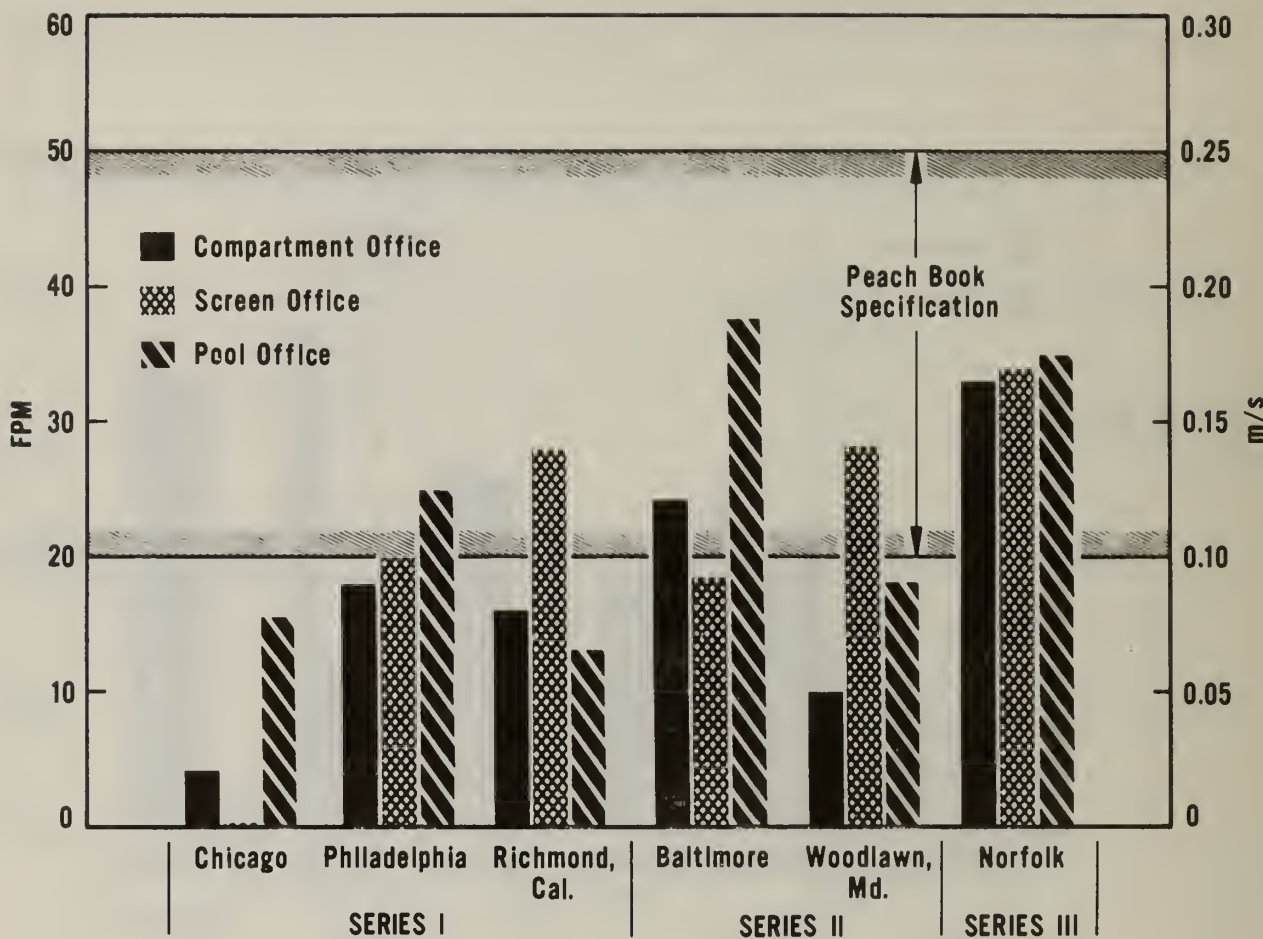


Figure 8. Specified and measured air movement at 4" (100 mm) above floor, compartment vs. screen vs. pool office arrangement

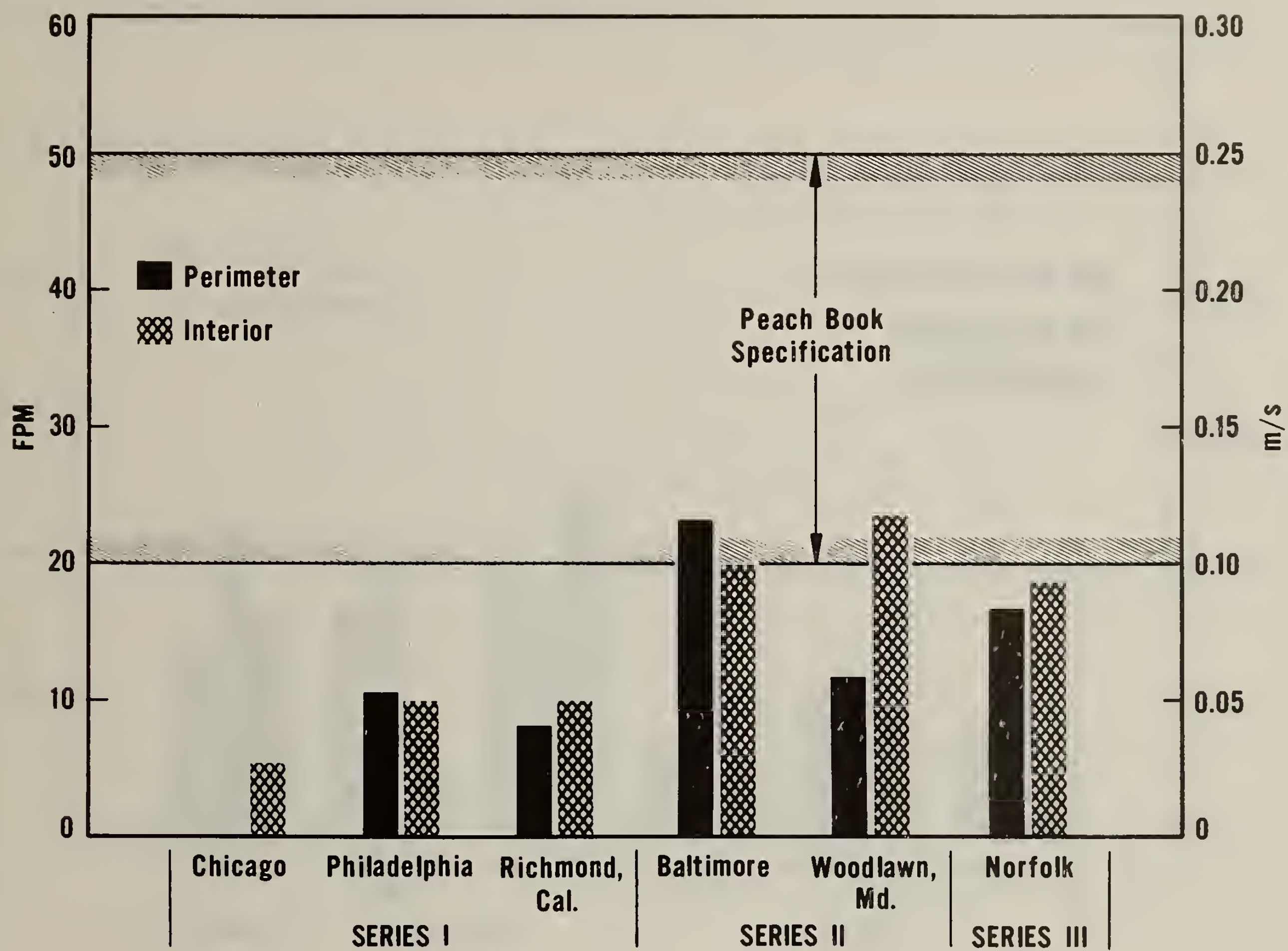


Figure 9. Specified and measured air movement at 24 in. (600 mm) above floor, by perimeter vs. interior locations

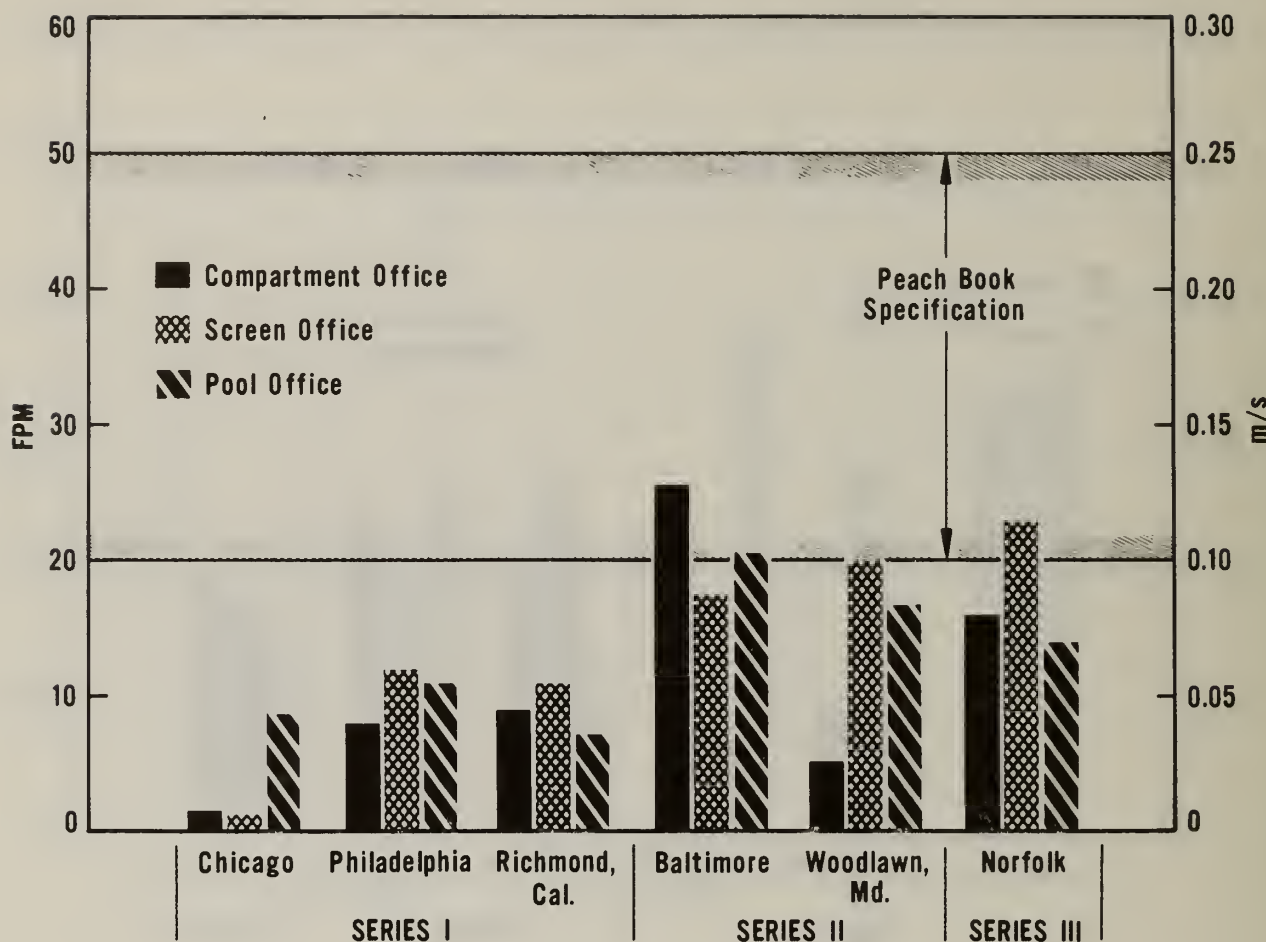


Figure 10. Specified and measured air movement at 24 in. (600 mm) above floor, by compartment vs. screen vs. pool office arrangement

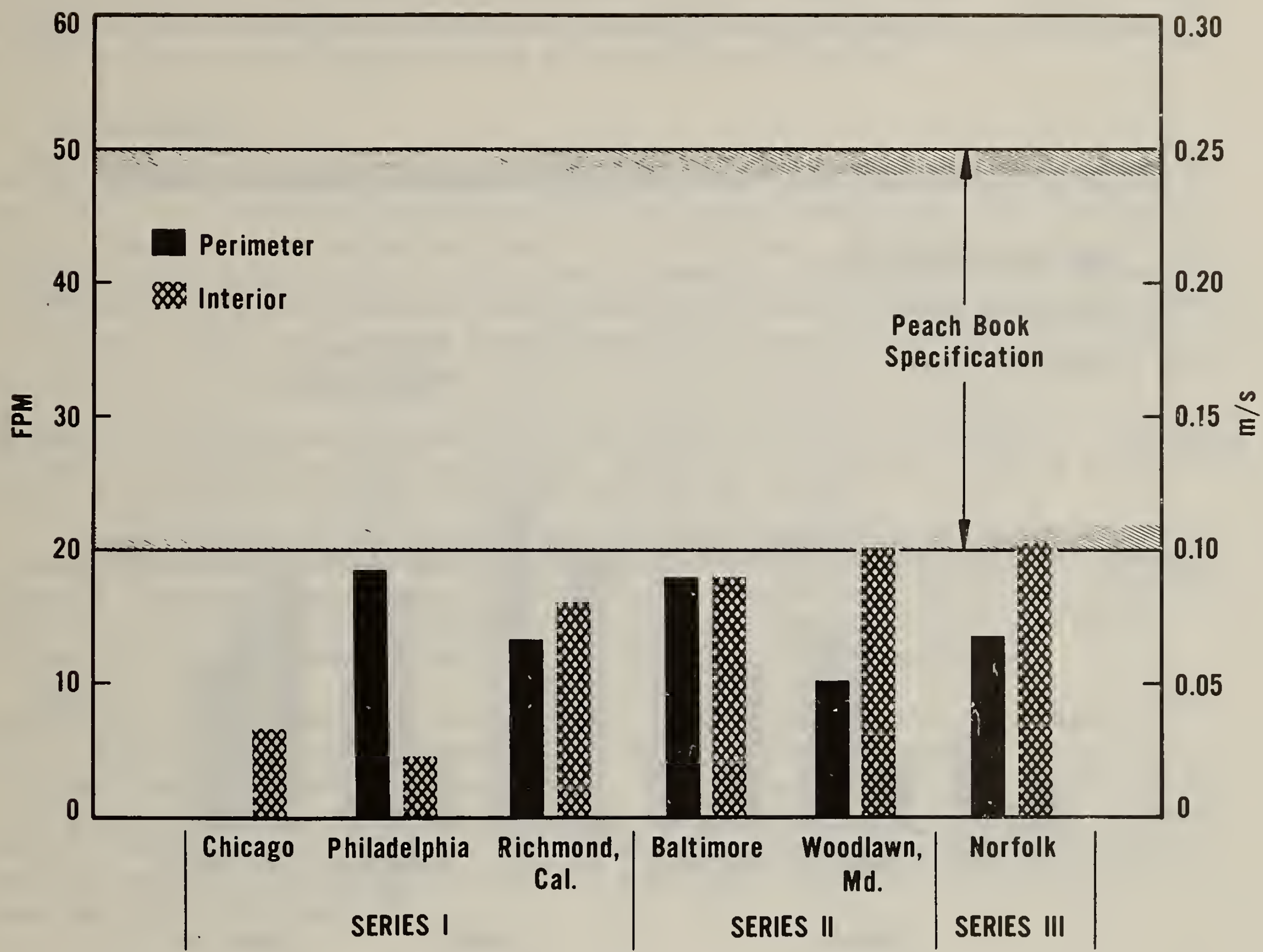


Figure 11. Specified and measured air movement at 43 in. (1100 mm) above floor, by perimeter vs. interior location

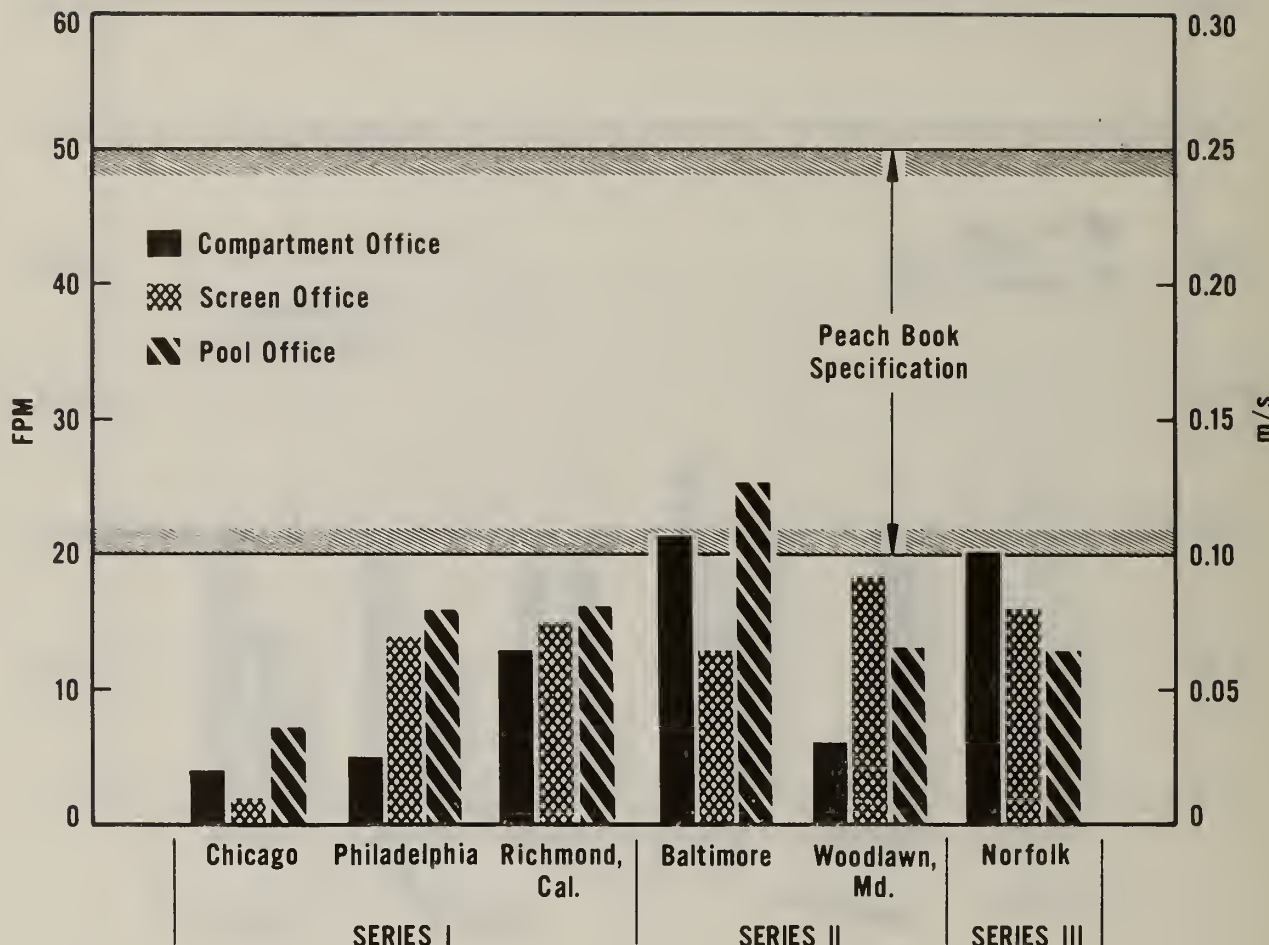


Figure 12. Specified and measured air movement at 43 in. (1100 mm) above floor, by compartment vs. screen vs. pool office arrangement

finding is that air movement systems in the BSP buildings do not, by and large, perform as originally specified in the Peach Books.

3.3 AIR TEMPERATURE

Figures 13 and 14 reveal that, with the few exceptions of local heat loads introduced by copying machines and occasional computer disc drives, the six BSP buildings are capable of maintaining the air temperature ranges initially specified in the Peach Books. Moreover, there is only little variation from the interior to the perimeter or from one office configuration to the other. But, as was remarked in section 3.7.5.5, the designs so finely tuned to one level performance may not be adaptable to a radical change in that level. This is a truism of engineering design: that peak efficiency must often be traded-off against adaptability. The result is that none of the BSP buildings ever approach the new operating temperature values later imposed on the Federal building stock in partial response to the 1973 Arab Oil Embargo. Those new values are mapped in figures 13 and 14 as FPMR D-48, D-60.

3.4 ILLUMINATION

The Peach Book's illumination specification changed markedly during the life of BSP. As was recounted in section 2.3.1, the specification for the first series of buildings keyed illumination levels to room sizes. Measuring room sizes and relating field measurements to them, while possible, would have both introduced additional expense and consumed great amounts of time in the field. Consequently, in figures 15 and 16 all field measurements are presented against the series II and series III criteria and the later imposed energy-conserving FPMR D-48, D-60.

Series II buildings are performing as specified. But the Philadelphia building of Series I and the Norfolk building of Series III are not performing at the levels stipulated in either the Peach Book or the FPMR.

As was described in section 2.3.2, illumination measurements were made at night, thus the discrepancies between interior and perimeter readings in the series II buildings -- illustrated in figure 15 -- may indicate lighting design that attempts to accommodate the daylight contribution at the perimeter.

Examination of the raw data revealed that the non-homogeneity of variance is due to very high illumination levels found in a number of special rooms (e.g., training rooms) and computer facilities. While figure 16 reveals no variations in lighting performance assignable to the spatial configuration of the offices, whether compartmented, screened, or pooled, the differences between buildings and between the three office arrangements are statistically significant (as measured by the "F-test").

3.5 ACOUSTICS

Figures 17 and 18 reveals that ambient sound pressure levels in the six BSP buildings are generally within the levels specified in the Peach Books. The exception shown in figure 17 is the interior zone of the SSA Computer Building, an area subject to the uniform drone of cooling fans located in the central processing units (CPU) racks and to the roar of the disc drives associated with the CPU's. But these zones are only intermittently occupied by human operators and repair personnel.

Figure 18 indicates that in four cases out of six pool offices tended to be slightly noisier but the ambient sound pressure level in all pools but one was

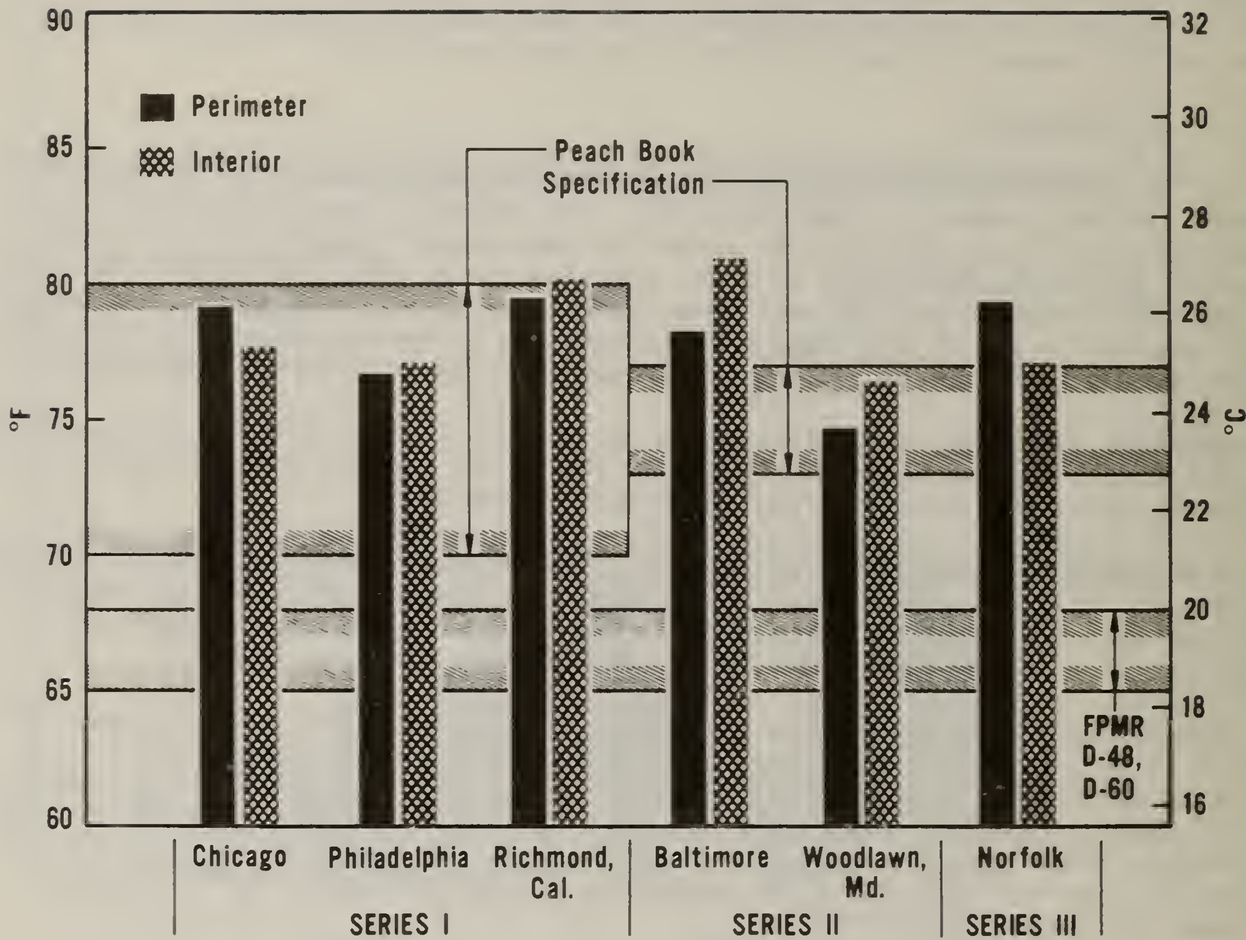


Figure 13. Specified and measured ambient air temperature, by perimeter vs. interior locations

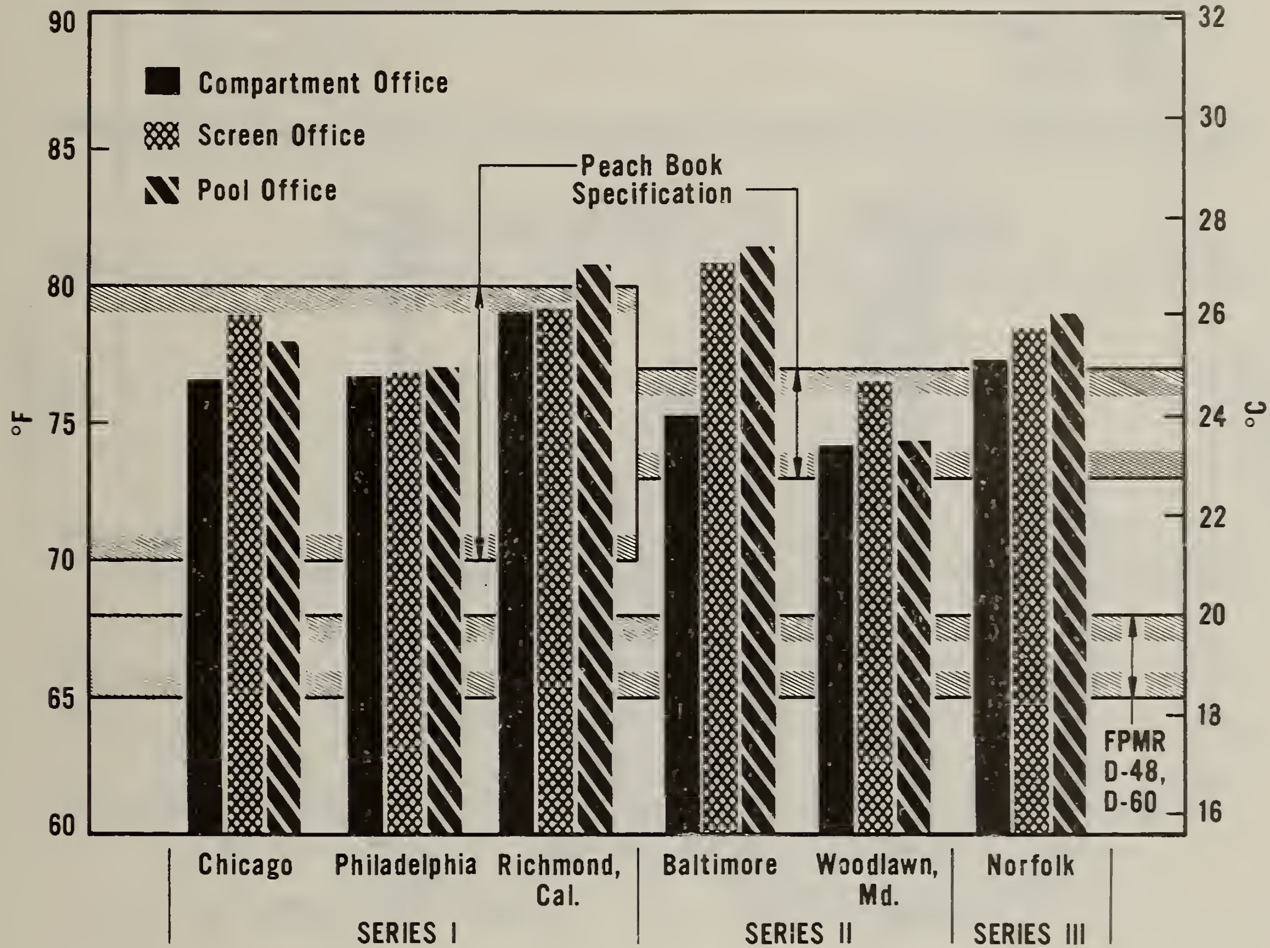


Figure 14. Specified and measured ambient air temperature, by compartment vs. screen vs. pool office arrangement

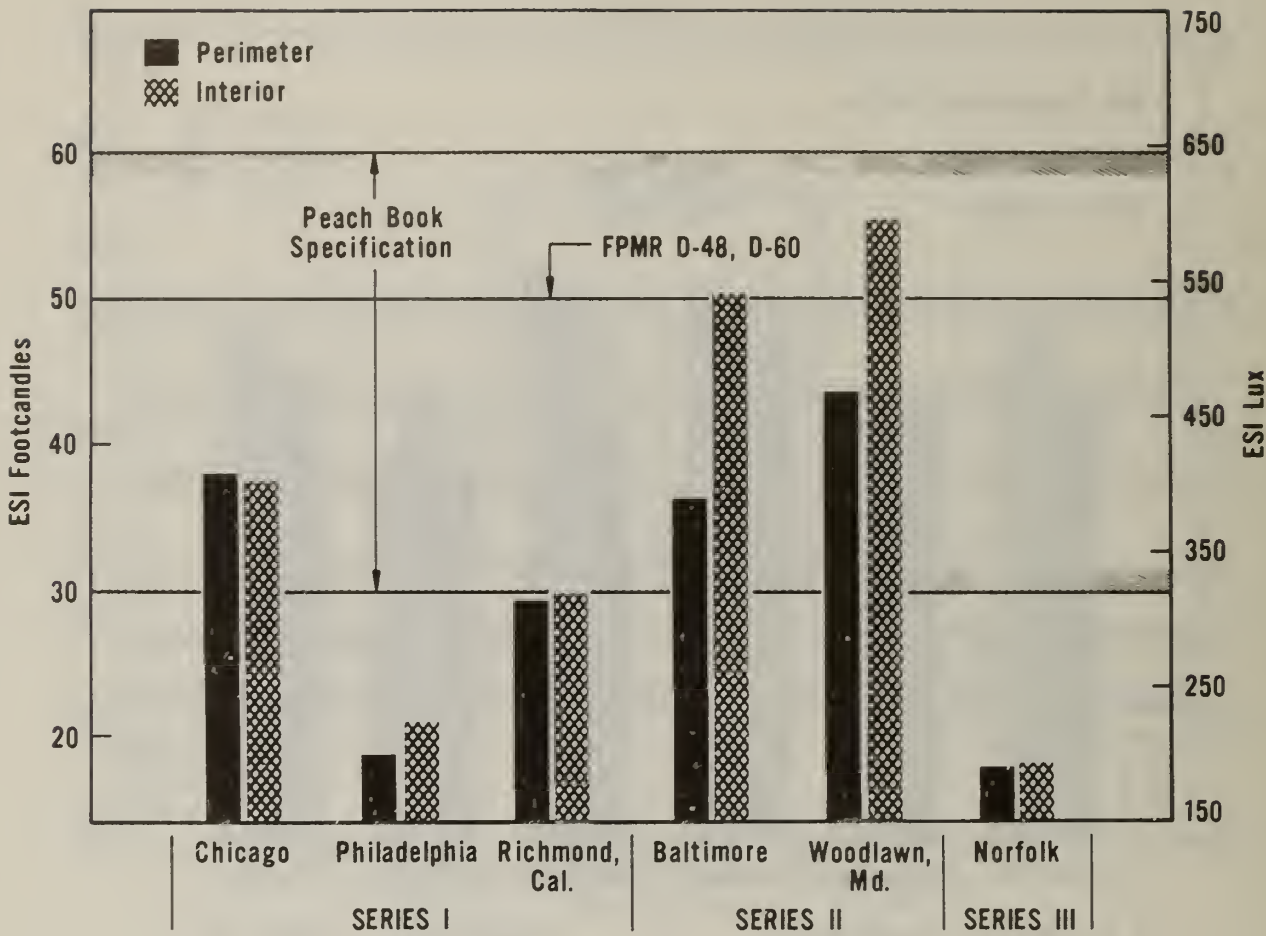


Figure 15. Specified and measured illumination, perimeter vs. interior locations

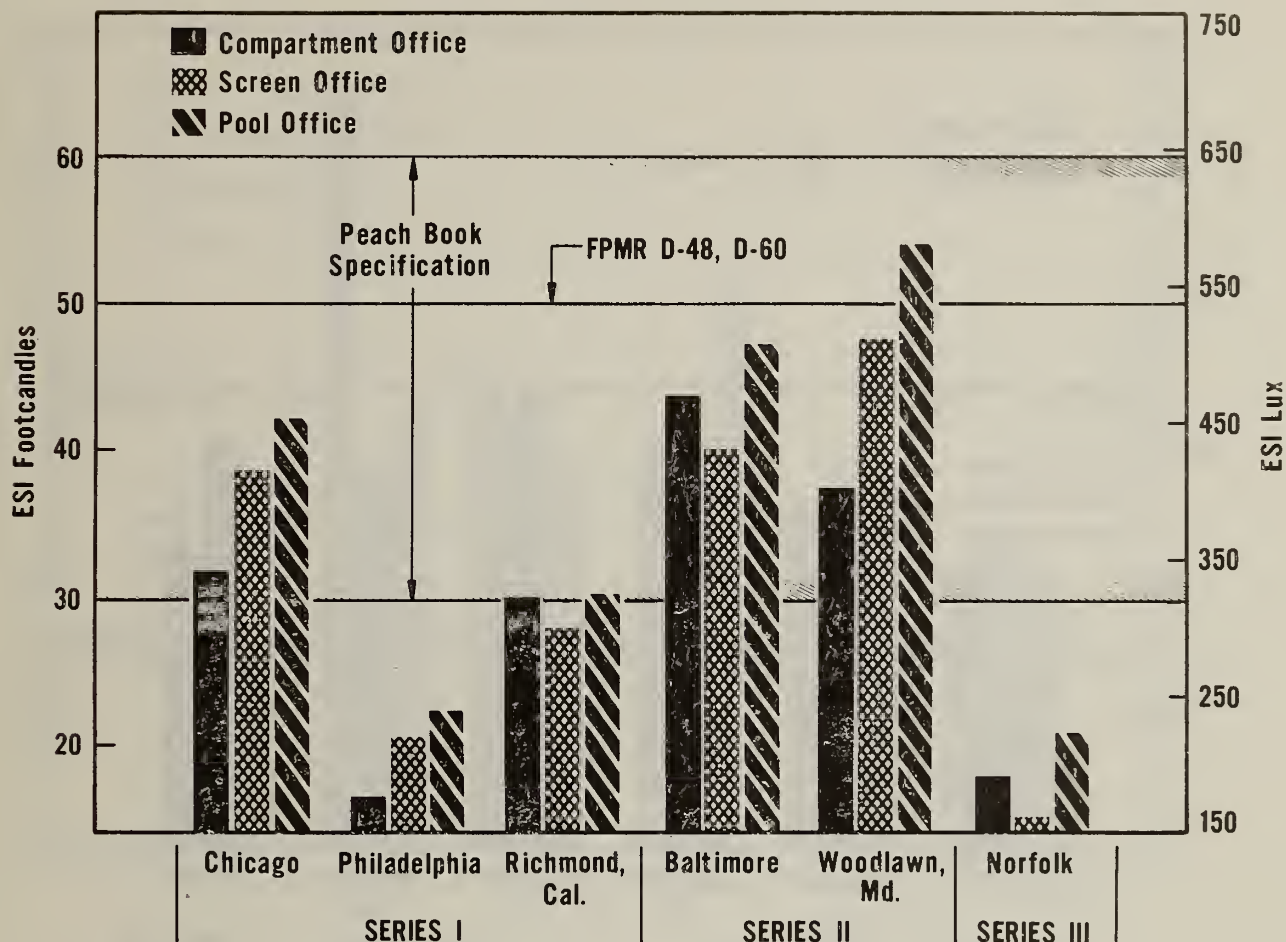


Figure 16. Specified and measured illumination, by compartment vs. screen vs. pool office arrangement

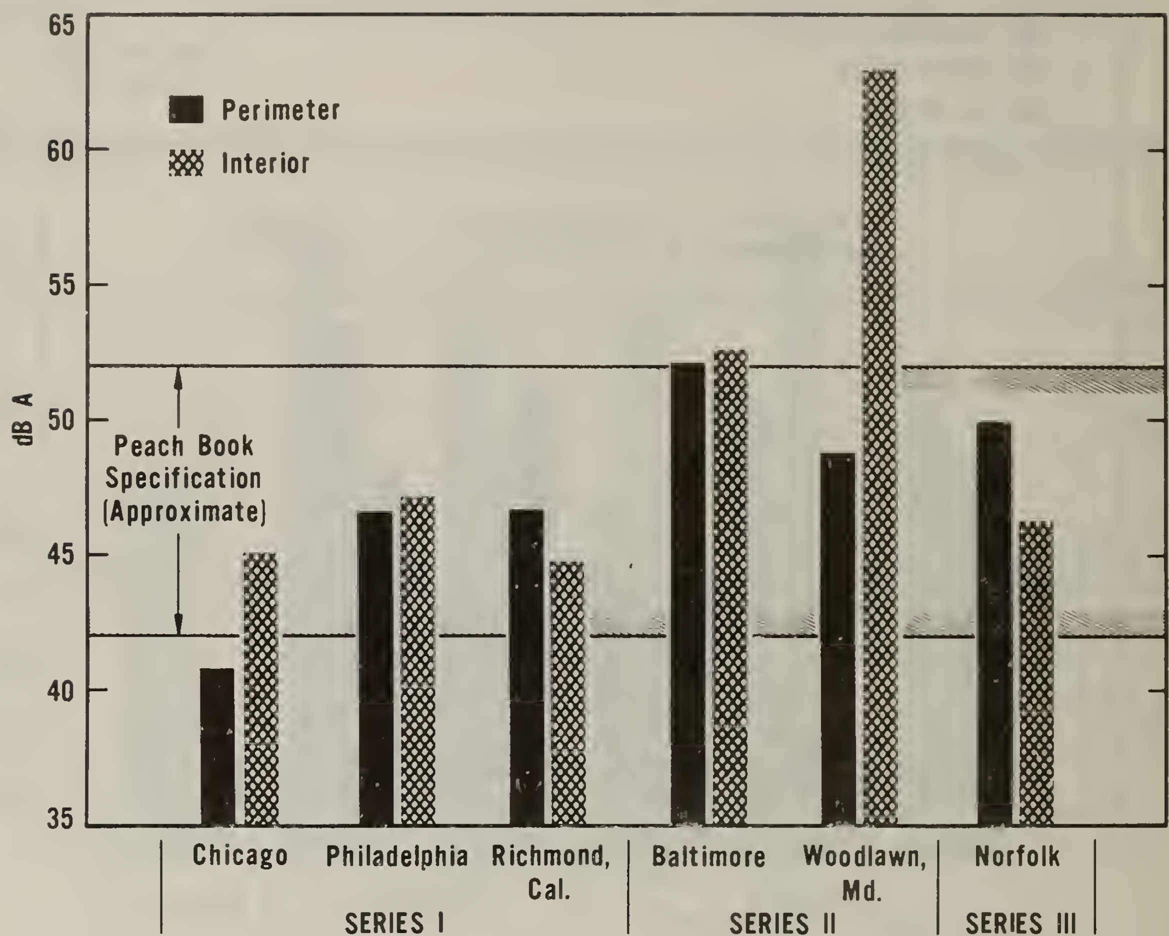


Figure 17. Specified and ambient sound pressure level, by perimeter vs. interior locations

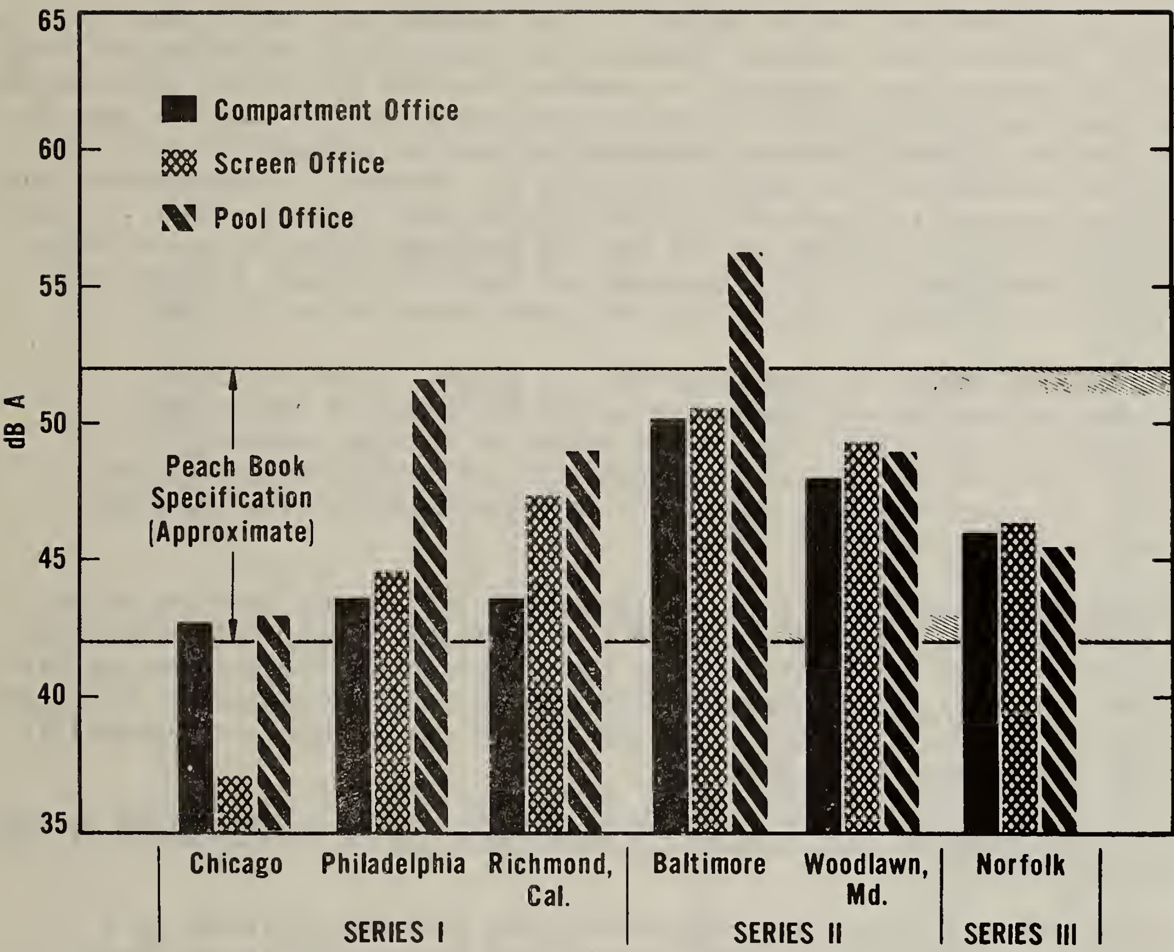


Figure 18. Specified and measured ambient sound pressure level, by compartment vs. screen vs. pool office arrangement

within the Peach Book limits.[1] The very low pool measurement for Chicago and the very high pool measurements for Baltimore are statistically significant

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1/ The anomalous signature of the Chicago building reflects the single occasion during the 18 days of field work that some of the sound pressure level readings were made outside the hours of peak office occupancy. This was due to a failure to anticipate the need to coordinate field measurement with the "flextime" then in effect at the SSA Great Lakes Program Center.

deviations from what would be expected by chance alone. Although Woodlawn's computer occupied interiors were the noisiest single class of spaces, Baltimore, overall had a significantly higher ambient sound pressure level of all the BSP buildings; it was at the upper limit of the acceptable range.

3.6 PLANNING (FLEXIBILITY IN INTERIOR SPACE DIVISION)

Every person interviewed on the subject -- GSA Headquarters staff, participating designers, producers and vendors, regional and field staff, including building managers and maintenance engineers -- remarked that the electrical distribution system (including office power, telephone, and signal wiring) was the most frequently changed building hardware subsystem in each of the six BSP buildings. (Observation during the site visits confirmed the remarks.) Consequently, the project concentrated its analysis in this single, most altered element. Table 7 contrasts occurrence of change in the six BSP buildings with the rates specified in the Peach Book for all subsystems but goes into detail in only one: electrical distribution. Data in the table were developed as follows:

> The maximum number of preset inserts for access to the subfloor communications ducts is estimated at one for every 25 square feet of the BSP interiors.[1] The annual number of changes expected, column (4), is the product of columns (2) and (3) and the total BSP floor area per series.[2] Column (5) is taken directly from the 1982 records in the GSA field offices.

The flexibility built into the BSP buildings has only barely been exploited. Put another way, the Peach Book appears to have vastly overspecified or overanticipated the need for flexibility in the BSP offices. The extenuating circumstances that mitigate the harshness of this finding are discussed in section 4.0 and section 3.7.5.8 reports the design team's misgivings over flexibility even while the design was in progress.

3.7 AN IMPRESSIONISTIC AND QUALITATIVE ASSESSMENT OF THE WIDER EFFECTS OF THE BSP INNOVATIONS

The performance of BSP building subsystems under service conditions is a relatively straightforward procedure because the Peach Book clearly specified performance levels and objective methods and associated instruments to measure these levels are available. But, as sections 6.2 and 6.3 of NBSIR 83-2662 argued in detail, methods for gaging the effects of the BSP innovations on the wider building community are, "compared to the measurement of technical results, still in the developmental stage." The results discussed in this section were developed from methods used by program evaluation specialists; the conclusions are, necessarily, tentative.

1/ See section 3.7.5.8 for discussion of subfloor distribution.

2/ Taken from table 1.1.

Table 7. Specified Rate and Measured Occurrence of Change in Six BSP Buildings, by Series, by Subsystems

(1) SUBSYSTEM	(2) ANNUAL RATE OF CHANGE		(3) AREA PER 1000 SQ. FT.	(4) ANNUAL NUMBER OF CHANGES EXPECTED IN EACH SERIES			(5) REIMBURSABLE CHANGES MADE IN 1982			
	PB:2	PB:3	PB:3	I*	II	III	I*	II	III	TOTAL
Structure (sprinkler)	0.035	0.035	25%	—	—	—	0	364'[a]	0	364'
HVAC	0.035	0.035	25%	—	—	—	0	0	0	0
Electrical Distribution										
Office Power	0.11	1.2	85%	4026-43921	4437	4990	98	504	7	609
Telephone	0.18	1.32	85%	6588-48313	7260	5489	6	16	7	29
Signal	0.15	0.375	85%	5490-13725	6050	1559	15	59	0	74
Luminaire Switching	0.035	0.035	25%	377	1412	146	0	0	0	0
Luminaires	0.03	0.03	100%	—	—	—	0	2	5	7
Finished Floor	0.10	0.10	85%	—	—	—	0	0	0	0
Finished Ceiling	0.10	included with other subsystems		—	—	—	0	0	0	0
Space Dividers										
Partitions	0.07	0.07	25%	—	—	—	9[b]	4[b]	4[b]	17
Screens	0.02	0.15	75%	—	—	—	(126')[c]	(115')[c]	(120')[c]	(361')

[a] 135' expanded metal from top of "in system" partition to underside of floor, 229' dry wall (both undertaken to enhance security).

[b] "occurrences" includes door installations but not rekeying of doors.

[c] total lineal feet of installed "in system" partition.

* Peach Book:1 specified planned change in a manner incommensurate, strictly speaking, with the specifications in the later two editions. Nevertheless, the PB:2 and PB:3 rates are used here to provide a high and low estimate for series I changes.

3.7.1 Introduction

Several experts who discussed the wider impact of the Peach Book procurements volunteered that the BSP represented a "high point" of their technical and professional careers; and while more than a few admitted having never worked harder in their lives, they also reported the satisfaction of a strong sense of shared purpose. The BSP apparently attracted some of the "best and brightest" in the building industry at that time; this was not only a great stimulation to further effort, it was, in itself, rewarding. Some spoke wistfully about that period; and although the experts were asked to focus their attention on the BSP process and product innovations listed in table 2.4, the series of individual discussions actually ranged broadly and several worthwhile insights emerged. These general observations will be summarized first, following the methods and using criteria provided in section 6.3 of this assessment's initial report, NBSIR 83-2662; the careers of the specific innovations will be recounted at the close of the present section.

3.7.2 Information Outcomes of the BSP

The information aspects of the BSP are successful if, because of the BSP, uncertainties are no longer a barrier to decisions about further uses of candidate technologies. The BSP certainly provided sufficient information on the several process and product innovations. But that information may not have been widely enough disseminated to constitute a genuine information success. Evidence for this statement, however, is mixed: one discussant (a business manager), checked off "yes" and "no" under the information subheading of table 2.4 and then remarked that the BSP was "highly informative for the participants but not for the rest of the industry." Another respondent (a designer and technical manager) remarked that BSP "didn't invent anything but did spread the word." That respondent's 1983 recollection echoes the 1975 comment by an officer of a building product manufacturing company that participated in two of the three BSP procurements. The vice-president of one of the Nation's largest construction materials producers said:

> We used products already on [the] market[1]....
> Instead of selecting items out of a catalog and trying to make them fit together -- as most independent architects and engineers would have to do -- we could evaluate whether it would be more economical to do modifications in the manufacturing process or in the field.[2]

He then encapsulated in one sentence an insight that might explain why procedures of building products and providers of design and construction services were drawn to the BSP:

1/ Publishers Column, Building Design and Construction, July 1975, p. 5.

2/ Charles E. Peck, then of Owens-Corning Fiberlgas, quoted in Gordon Wright, "How the Team Assembled the Biggest Systems Package," Building Design and Construction, July 1975, p. 32.

"We really didn't end up with new products but [with new capabilities, and] if we can market these capabilities we'll end up marketing our products.[1]"

Thus, the precise character of the BSP principle innovation may turn out to be elusive because it is immaterial. Ironically, the lasting impact of over 4 million square feet of construction may turn out to have been an intellectual one.

While it would take an elaborate survey beyond the resources of the present project to determine finally which of the several previous commentors was correct, there is indirect evidence that the BSP word was getting out. One indicator was that the BSP did not attract wider industry participation as it evolved. Qualifying consortiums of vendors dropped from nine at series I to two at series III.[2] What accounts for this lapse of interest?

BSP participants offered their own explanations for this decline: many prospective suppliers "were in just to learn [about the performance approach]," in the words of one participant; another remarked that the initial GSA effort to acquaint large numbers from the center and the fringes of the building community drew some "mad inventors who were weeded out early."

So an explanation for this decline may be that sufficient information developed in series I to give prudent building product suppliers and design firm managers pause before launching further efforts in the later procurements. This interpretation is supported by data illustrated in figure 19, whose vertical lines represent the approximate dates of contract awards for the three BSP procurements. Figure 19 reveals that the fall-off in vendor interest occurred at the very time when the demand for public and, particularly, private nonresidential building was falling. Office buildings are a large component of both declining categories and business economics teaches that the fall-off of demand stimulates suppliers to market more aggressively their products and services by offering lower prices or enhanced service. Indeed, this argument is used in support of using government construction expenditures as a counter-cyclical corrective for a lagging national economy. But exactly the reverse seemed to have happened in the BSP's procurements: fewer vendors came forward during the periods of slackening demand and it is entirely plausible that the BSP's information success, itself, led to a lower level of program participation.[3]

1/ "How the team ...," p. 33.

2/ NBSIR 83-2662, p. 23.

3/ NBSIR 83-2662, p. 36, footnote 2.

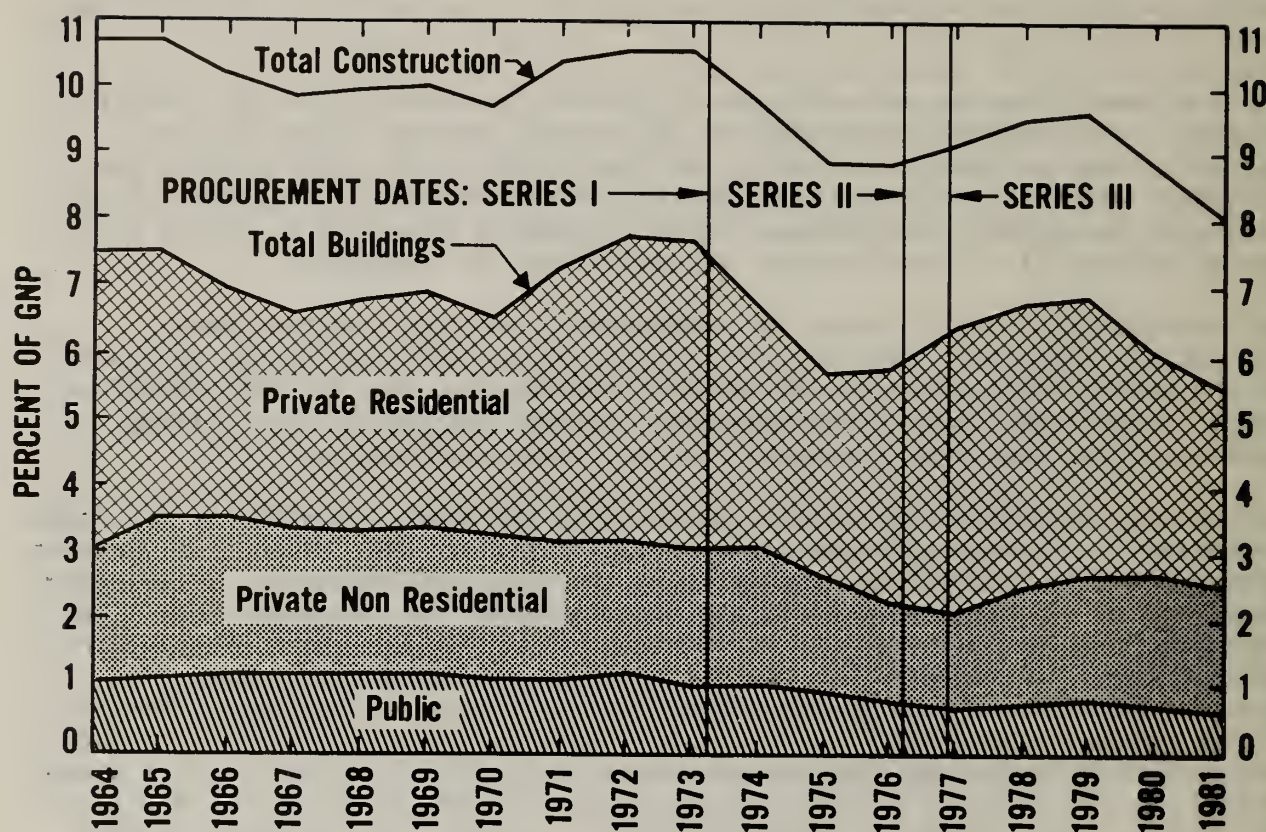

Figure 19. Annual construction and building expenditures as proportion of the Gross National Product (GNP) at the time of the three BSP procurements. Source: U.S. Bureau of the Consensus.

3.7.3 Application Outcomes of the BSP

Application success occurred when the installed innovative systems reliably delivered the performance the BSP designers initially specified. The measurements of delivered performance are reported in figures 6 through figures 18 and are discussed in detail in sections 3.1 through 3.6.

3.7.4 Diffusion Outcomes of the BSP

Diffusion success is measured by the extent to which a technology (whether a process or a product) has, consequent to the BSP, and not merely subsequent to it, passed into wider use in the building community. This is exceptionally difficult to measure, however, because, as a building products executive observed during the BSP, most of the individual items came "off the shelf." A participating designer/manager remarked years later that BSP "didn't invent anything, but it did spread the word."

It was this ability to "spread the word" about a product's performance that gave the BSP a large role in accelerating industry acceptance of products and practices. How this came about is described in the words of the chief executive officer of a building products company who participated in BSP while previously employed by one of the successful joint-venture contractors:

> "Identification of a product with a major procurement [like BSP] is not, in itself, a means to larger sales in subsequent years; what matters is that the product has been independently certified [during the BSP] as meeting a given performance specification. That is what sells."

Although certifiable performance is a valuable asset for increasing building product sales, the specific performance levels sought in the BSP procurements may have, ironically, reduced the extent of diffusion into the general building community. Two related but distinct reasons for this self-limiting diffusion were offered by two discussants. In the first place, said one mechanical engineer familiar with big-city markets for new office space the Nation over, the Peach Books were "over-precise" denying building owners and their designers room to trade-off one performance aspect — say, appearance — against another -- say, ease of maintenance. The Peach Book specification "tied down too many parameters of performance" (seven attributes were specified for most of the seven hardware subsystems[1]), leaving too little leeway for the owner and designer to negotiate between price and performance. Secondly, as a building products marketing specialist pointed out to the project, the private sector market is incredibly varied compared to the relatively monolithic and uniform Federal building market. Consequently, building products marketed to the private sector must respond to a much greater range of cost and performance requirements: from the one-of-a-kind, prestige-laden office building serving as a corporate "flagship," to the aesthetically bland, spatially neutral speculative office building catering to a diverse range of potential tenants, to the strictly utilitarian office structure that is merely an adjunct to a production facility.

1/ NBSIR 83-2662, section 2.8 and figure 2.2.

3.7.5 Comments on Specific Innovations

3.7.5.1 Integrated Research and Design Teams

Use of combined research and design teams, while still not commonplace, have grown impressively in recent years, spurred largely by the need to make more effective use of building energy.[1] In retrospect, it seems strange that something so useful was so long in coming, requiring a deliberate break with precedent in the Government's procurement of professional building design and consulting services. But, viewed from the perspective of the early 1970's, the use of an integrated team to "design, fabricate, install, and maintain for 9 years a building system which will create the office space [for three buildings]"[2] was a departure from professional practice in the private sector as well. Consider the comments of a marketing manager from one of the building products firms that participated in a winning joint venture:

> "In the conventional design process the interface between structural, mechanical, and electrical aspects of a building turns out to be a void, yet this is the heart of a building and makes it live and breathe.[3]"

While integrated teams are now more frequently encountered, there is no specific evidence that their diffusion is traceable to the BSP experience. The fact that integrated teams were used repeatedly through all three series of the BSP effort, on the other hand, suggests that the teams were an "application" success. To what extent did the early use of teams constitute an information success? Only one specific negative finding was found among those interviewers: the integrated teams found it "hard to work in a programmatic vacuum." The designers and researchers never knew exactly where their in-system components would be installed nor exactly which agency functions they would house.

A vacuum of another sort made some industrial participants apprehensive. One systems consultant recalled that prospective vendors reviewed the initial drafts of the Peach Book but then hesitated to participate because the specific buildings to which the new methods were to apply had yet to be designated. Nor was it certain exactly when the procurements were to be made. Those prospective participants withdrew until those administrative and budgetary uncertainties were removed and there would be minimal delay between approving a definite building project and the participant's sale of specific products and services.

1/ See, for instance, "Changing Relationships in the Design Process -- a Roundtable," ASHRAE Journal, Vol. 23, No. 6, June 1981, p. 48 and ff.

2/ "GSA Declares System Prototype a Success," Actual Specifying Engineer, November 1974.

3/ "How the team ...," p. 33.

A final information success was, in the estimation of one architect, the identification of the need to develop in all future integrated teams a document listing what each team member does at the technical level at each stage of submission. "Only then," according to this project manager, "could we price the job [because we could go] through and figure out for ourselves how much time was associated with each [research and design] task." Once these roles were specified and made known to all participants and observers, then resultant peer pressure kept designers and researchers on track, on time, and within budget. "[Because] everything is being done in the open," remarked an executive who participated in all three BSP series, "and there is a lot of spotlight [sic], it did speed up the governmental process, because government does not like to start designing and delivering buildings in 3 years. That government building process usually takes from 5 to 7 years, you know."

3.7.5.2 Life Cycle Costing Economic Analysis

The life cycle costing innovation had its greatest success in the information and application stages but did not diffuse widely in the form developed during the BSP. Still, this episode is worth recounting because this innovation was a sharp and lasting break with Government building procurement practices.

The PB:1, issued in January 1971, estimated that the total costs of conducting business in an office building over a 40 year economic life may be disaggregated as follows:

2%	to design and build
6%	to operate and maintain
92%	for the wages and salaries of those employed in the completed structure[1]

A systems consultant recalled 12 years later some of the apprehensiveness about breaking building procurement precedents:

> That percentage breakdown came from NBS and we were trying to find a way to make that work as a basis for building procurement. Remember, now, [then-GSA Administrator] Arthur Sampson was saying "We've got to find some way to buy the cheapest building to use, not the cheapest building to build." And so, we invented a [life cycle costing] formula -- which we later tuned up -- that went into the first Peach Book.

Energy, it developed, dominated all other cost considerations, and this even before the 1973 Arab Oil Embargo. The life cycle costing effort, with energy dominating, remained through all three series of the BSP in the form summarized in figure 20. Moreover, the life cycle costing formula, as it was subsequently refined, proved so universal that the system contractor for the Norfolk building (Series III) was able to provide as part of the "in-system" procurement package the heating and cooling subsystem's central plant that all previous BSP

1/ PB:1, p. B-8.

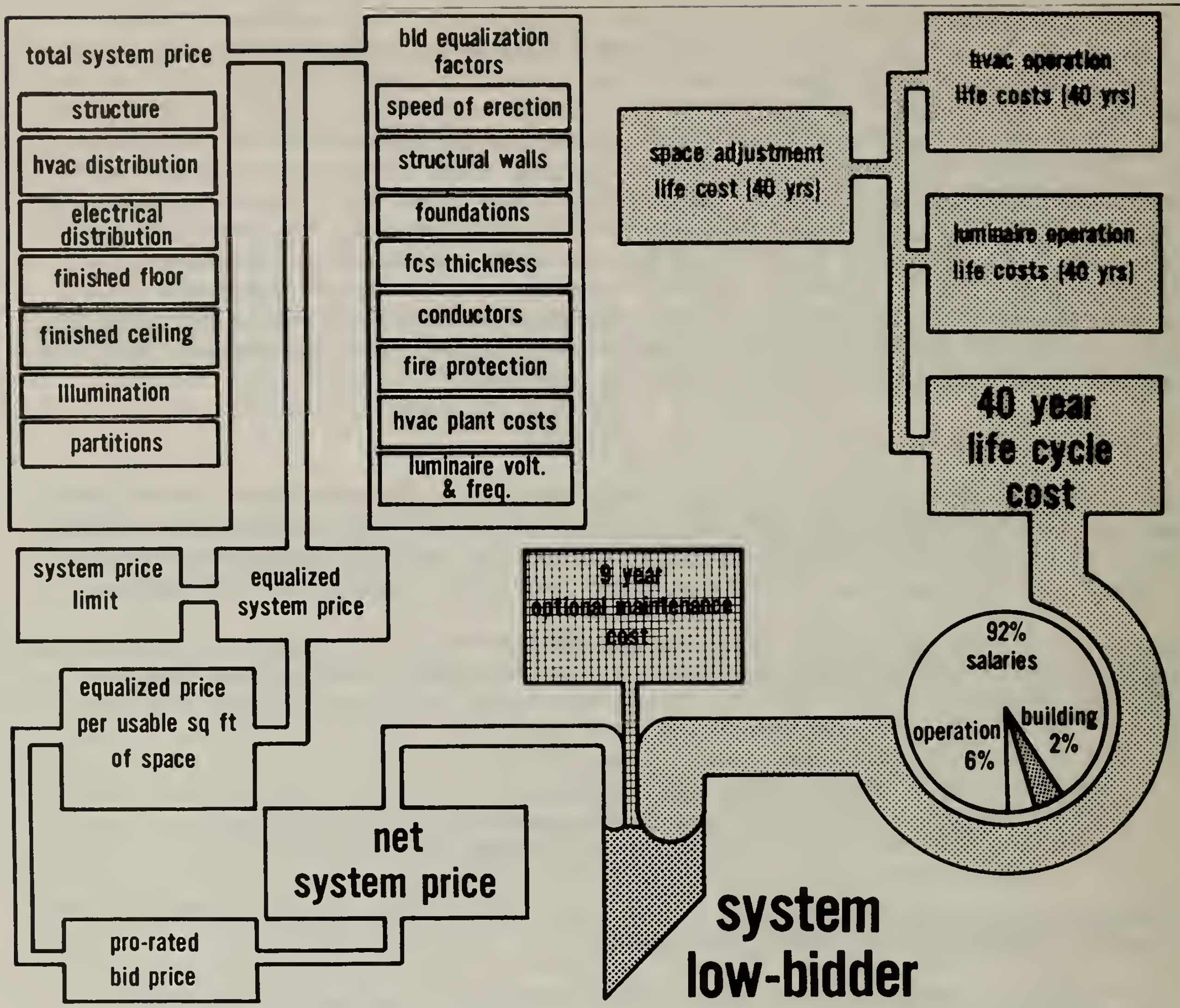

Figure 20. Basis of BSP awards. (Adopted from the Leo A. Daly (unpublished) report to PBS, "The System Approach for Building Acquisition: A Case History of the GSA/SSA Program Centers System Building Project: 1971-1975,"January 1976, p. 87.)

contractors held out of system. The successful Norfolk contractor interpreted PB:3 provisions differently and, in the words of a consultant to GSA/PBS, "he could make a better deal for his package by providing the central plant than by letting it remain out of system." (This is also an example of the advantages of the previously discussed integrated research and design teams who can optimize across a wider scope of building services.) This was a clear instance of application success.

For all its information and application success, however, the Peach Book's formulas were not widely used and have, in fact, been attacked by the Comptroller General.[1] Moreover, the Chairman of ASTM Subcommittee E 6.81 Building Economics indicated that the BSP precedents were not cited as a stimulus to that subcommittee's effort to develop standard terminology and methods for assessing the economic performance of building construction.[2]

What might account for this neglect of the specific life cycle costing formula? The chief executive officer of a building products company, who had served as a project manager during the series I and series II BSP procurements, remarked that:

> Life cycle costing is not brand new. Every business decision does it. The novelty with the BSP was in applying a single [formula] to many buildings with many participants.
>
> Private firms work totally differently from government. For one thing, the cost of money, something virtually ignored by public agencies[3], is a very real concern when you have to go to the market for capital.
>
> Even projects financed within the company must compete on a "return on investment" basis with the development projects of other divisions.
>
> The other thing is that private firms differ among themselves: What is capital investment, what items are 'expensed' as costs of doing business varies depending on your accounting approach.

3.7.5.3 Speech Privacy Potential Acoustical Test

The innovative Speech Privacy Potential (SPP) acoustical test was an "information success" because private firms were given enough technical performance criteria to produce acoustical ceiling panels for government

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1/ General Services Administration's Use of New Construction Concept for Federal Buildings Not Yet Successful (LCD 77-322), Washington, U.S. General Accounting Office, October 6, 1977, p. 22 and p. 38.

2/ Personal communication. Further background on the Subcommittee's work and its impact on industry and government is reported in Harold E. Marshall's article in ASTM's Standardization News (October 1982), pp. 26-30.

3/ The President's Private Sector Survey of a Cost Control (Grace Commission) makes this point also. See PPSSCC Task Force Report on Federal Construction Management, May 17, 1983 Meeting Draft, p. 66.

procurement. New products were introduced for sale to the wider building industry, on the basis of their being certified as having met the SPP criteria.[1]

Section 3.5 discusses, and figures 3.4.1 and 3.4.2 illustrate, SPP's "application success" in the six buildings erected during the BSP. But, as discussed in section 2.4, the precise SPP procedure was too cumbersome and expensive for NBS/CBT to use and it is this difficulty in the operation or execution stage that has retarded the diffusion of SPP into wider practice.

Acousticians acknowledge that SPP is the "only proven performance specifications for components.[2]" The novelty of the SPP testing procedure, carried out both in actual offices or in laboratory mock-ups, is that it considers those components not singly and in isolation but in the total system of component and environment. This systemwide basis of testing is acknowledged to be a significant break from the past, but experts active in the work of ASTM Committee E33 on Environmental Acoustics have remarked that the criteria for acceptance within SPP are:

> "too sensitive, with a one-dB margin between pass and fail. The method is generalizable but the tests are too precise because of the exact positioning of sound sources, test specimens, and receiving stations."

Moreover, some of the hardware called for in the SPP are both idiosyncratic (particularly with respect to directivity) and "hard to get."[3]

ASTM E33, building on SPP precedents, is developing a series of related, standardized objective tests using more accessible, less idiosyncratic equipment. Beyond that, and at some future time, ASTM E33 will devise subjective test procedures and other items which, used together, will likely succeed SPP. In the meantime, and because Federal acoustical procurements are so large, the Nation's principal acoustical testing laboratories already have, or are about to, set up the test chamber layouts required for testing to the GSA/PBS C.1

1/ A brochure advertising acoustical ceiling panels to designers and installers describes the products in this language, including the parenthetical statement:

> 1-1/2" thick boards are designed to comply with GSA PBS C.1 and C.2 test criteria for speech privacy in an open office. (This is the most stringent acoustical requirement of components in the open office.)

2/ David A. Harris, et al., Planning and Designing the Office Environment, (New York: Van Nostrand Reinhold, 1981), p. 63.

3/ Personal communication from a past Chairman of ASTM E33.

and C.2 specifications that incorporate the SPP approach.[1] But because of the expense entailed, these testing facilities are still relatively rare.

3.7.5.4 Prequalification for Public Procurement

In retrospect, it may be fair to ask whether or not the "Two-Step Process" and the consequent prequalification for public procurement and the performance approach it embodied — each described in this project's initial report[2] — were innovations at all. In the first place, a now-retired Federal engineer, who was present at the creation of BSP when the idea for it emerged from NBS in 1965, remarked that the then-current Federal Procurement Regulation[3] permitted both the two-step and prequalification procedures. But to not explicitly proscribe a method is not the same as actively promulgating it. And in making these methods more visible to and accessible by the wider building community, the BSP acheived "information success" for its procurement methods incorporating the performance approach.

An indicator of how the BSP reduced uncertainties about innovative procurement practices are these remarks, the first by a vendor who failed to win a procurement award and the second by a manager who remained with BSP over its entire course:

> The Two-Step method is good for sorting out and choosing from among many technical alternatives to solving a design problem.
>
> If you consider the three procurements consecutively, you realize that the organization of the management of the project looked more normal, the contractor response to the procurement looked more normal. We learned a new approach and got used to it.

Application success — the extent which GSA/PBS, its advisors, and government auditors are satisfied with the innovative procurement processes as applied — has been reported by others, notably the U.S. General Accounting Office[4], and needn't be repeated. One difficulty did emerge and bears reporting because it testifies that, contrary to widespread belief, the building industry is dynamic and its component products are continually improved. This technical dynamism generated some difficulty because the length of the two-step procedure exceeded

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1/ The author has observed SPP testing in progress at the research and product development laboratories of three producers of acoustical building materials and components.

2/ NBSIR 83-2662, sections 2.6 and 2.7.

3/ FPR, subpart 2.1.

4/ General Services Administration's Use of New Construction Concept for Federal Buildings Not Yet Successful, LCD-77-322, October 6, 1977; What Has GSA Done to Resolve Previously Reported Problems in Its Construction Program, PLRD-81-7, March 27, 1981 the development time for minor improvements in the hardware components that integrated research and design teams were evolving. The situation was made worse by the effort to make performance-based procurements scrupulously fair.

Fairness in administering a performance-based procurement requires that the purchasing agency do at least two things: 1) promulgate explicit acceptance criteria, preferably quantitatively measurable, and 2) define repeatable evaluation methods for use in the profession's ascertaining whether or not those criteria will have been met by whatever candidate technologies are offered by competing vendors[1]. But the detailed design of subsystems continued to evolve after criteria were promulgated and methods defined so that, in the words of a successful joint-venture vendor:

> The Peach Book couldn't change fast enough. Having locked in early on criteria and methods, some interesting new ideas never got into the first procurements.

Diffusion success was not achieved because stimulus of Federal BSP procurement was discontinued in the late 1970's. One centrally involved figure -- whose architecture-planning-engineering firm continues to offer performance-based procurement methods to private and public sector clients the world over -- reluctantly acknowledged this in an interview:

> Oh, I think my biggest disappointment was that it was not universally accepted. A few people are trying to use performance, you know, in terms of specifications for specific items. But people aren't buying whole buildings using this system. That's a disappointment.

This disappointment is truly ironic because within months of this interview the Reagan Administration's advisors, the President's Private Sector (Grace Commission) Survey on Cost Control (PPSSCC), recommended increased use of performance specifications, estimating that such use would yield annual savings of $400 million in Federal construction obligations.[2] Moreover, the Grace Commission acknowledged GSA's internal critiques of prescriptive guidelines and estimated that performance-based procurement was applicable to 100 percent of the new and rebuilt building inventory.

1/ A useful guide to this approach based on experience in several countries since the pioneering GSA/NBS effort is the International Council of Building Research Studies and Documentation (CIB) Report, <u>Working with the Performance Approach in Building</u>, Publication 64, January 1982, available from the CIB Secretariate, Postbus 20704, NL-3001 JA in Rotterdam, Netherlands.

2/ <u>PPSSCC Task Force Report on Federal Construction Management</u>, May 17, 1983, meeting draft. The Task Force's Recommendation 18 on increased use of performance specfications is discussed in section II.B, "Design and Construction," pp. 115-123.

If GSA/PBS's termination the BSP within seven years of its first design contract award is claimed to have been hasty, as having not allowed sufficient time for monitoring needed technical and institutional innovation, then many other Federal demonstrations have been criticized for the same thing; namely, that large-scale government purchases of innovative technologies -- the inducement offered qualifying private sector vendors -- are curtailed before technically-sound innovations are ready to meet the market test on their own. The General Acounting Office's (GAO) exhaustive 1976 analysis of the Department of Housing and Urban Development's (HUD) Operation Breakthough,[1] conceded that the "suspension of major government-subsidized housing programs" was a "prime contributor" to Opertion Breakthrough's lack of success.

Lapse of Federal commitment part way through a demonstration is not unique to Operation Breakthough or to the BSP. When GAO examined 65 HUD demonstrations from 1974 through 1981, it was prompted to warn:

> Demonstrations sometimes take longer than their initiators anticipate. When unrealistic time contraints are put on them, however, they can fail. Moreover, demonstrations can be completed at times when the policy purpose they were designed to serve is no a longer critical issue on the public agenda. Therefore, it is important in planning to make a realistic analysis of time -- the time required to complete the demonstration and the time that defines the policy purpose being served.[2]

These lapses in the Federal commitment to go "all the way" in the procurement stage have made the private sector wary of participating fully in government-sponsored demonstration projects because it is only through volume production that the "front-end" research, development, and engineering costs can be recovered by the firms responding with advanced technology. Some prospective BSP participants revealed their apprehensions about this by 1976, early in the BSP effort.[3] After all, the curtailments of the Operation Breakthrough housing purchases were still fresh in the building industry's memory at that time.

If the Federal purchase commitment wavered, the commitment of some building product firms -- having once entered the product development cycle stimulated by the BSP performance specification -- remained strong. The BSP required a redefinition of building hardware subsystems in terms of the performance expected of the subsystems. That redefinition led not only to a reconceptualization of the designer-supplier-contractor relation -- one such was described in

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1/ Operation Breakthrough -- Lessons Learned About Demonstrating New Technology, PSAD-76-173, November 2, 1976, 87 pp. The specific quotation is on p. 17.

2/ HUD Demonstration Programs -- Their Use as a Policy Tool, GAO/IPE-83-4, March 8, 1983, p. 40.

3/ "All Eyes Are on the GSA's 'Upkeep' Contracts," Business Week, June 21, 1976.

section 3.7.1 -- but in some cases a thorough rethinking of individual building components. A vice-president of a worldwide design and planning firm who served as a systems consultant to GSA/PBS in all three BSP procurements traced this evolution of a single product by a competing firm by recalling:

> About quality? Well, I think that the quality was improved in basic subsystems by the manufacturers. The manufacturers were doing what GSA originally hoped they would do [namely,] once the performance was defined they would continue to upgrade and revise their subsystems to respond to that performance [specification]. The quality improvement that I mentioned, the electrical, improved dramatically, even though there was no change in the performance specification, it stayed really rather constant.
>
> The electrical distribution is fascinating if you want to look at what happened in response to performance specifications. The first series [of buildings] we got "off the shelf" stuff basically, with some little modifications. The next series the offerors (manufacturers), had done a lot more inventing and some tuning up. There was a significant advancement and not only in the winning offer but all the other [unsuccessful bidders] and you can see [the result of] it in Sweet's catalog. Their [product] lines improved to where now if you look in the third series, for example, we've got [H.H.] Robertson's, "Tapmate". Look at the Robertson "Tapmate" system today that is in Sweet's catalog, it's got neat things, all kinds of capabilities and it's absolutely in direct response to the performance requirement and it's fairly well spelled out in the advertising text.
>
> Incremental product improvement based on unchanged but well articulated performance requirements was one way the quality changed. The other way the quality changed was we changed performance requirements. The lighting in series I was very conventional, we got much better lighting in the second go-round because we changed performance requirements.[1]

3.7.5.5 Integral HVAC-Luminaire-Fire Protection Package

Contemporary accounts in the professional press reported that combining lighting and HVAC subsystems enabled the Owens-Corning Fiberglas/Wolf and Munier joint venture awarded the series I procurement to estimate energy use at half the rate used for conventional buildings.[2] The total package, devised

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1/ The series-to-series changes in the lighting specification are discussed in section 2.3.1.

2/ "The Government Building, Performance Specified Energy - Integrated and Life Cycle Costed, Point the Way to the Future Mode of Construction," Building Systems Design, October/November 1974, pp. 4-10.

by Gershon Meckler, then-president of Loring/Meckler Associates, energy consultants of Washington, D.C., integrated a double induction terminal and with a water-cooled luminaire system manufactured by Westinghouse. The Westinghouse water-cooled luminaires, marketed under the trade name "Constant Aire" functional like simple heat exchangers in the shape of a standard fluorescent fixture. Water from an evaporative cooler, passing through tubes that were an integral part of the fixture, absorbs much of the luminaires heat. Thus, most of the heat of lighting never reaches the occupied space. In winter, this excess heat was to have been used to preheat outside air. (This did not always occur, however, and the General Accounting Office's evaluation of the BSP was severely critical of this lapse.[1])

This system was intended to reduce HVAC energy requirements by reducing lighting heat in the space and by reusing normally wasted lighting energy. Furthermore, the light output of the cooler fixtures is increased to the point that three, rather than the usual four, tubes per fixture, are ample to provide the required illumination. (In the "delamping" GSA/PBS practiced in partial response to mid-1970's increases in energy prices, these three tubes were reduced to two.[2])

Overall construction costs were further reduced by combining the luminaire's copper water-coolant piping with the life safety sprinkler piping system. This saved the cost of an extra piping system and provided an all-sprinklered building with consequent economies in rendering the structural system fire resistive.

As may be inferred from the detailed coverage the professional press expended on the initial BSP procurements and the hardware systems they incorporated, the integrated package was an information success. But, except for connecting luminaire cooling pipes to the sprinkler system, was it truly a technical innovation? After all, air- and liquid-cooled luminaires were in wide-enough use by 1968 -- 3 years before PB:1 was published -- to have stimulated the Illumination Engineering Society (IES) to begin developing standard test methods for them in that year.[3] Moreover, liquid-cooled luminaires were described in detail and their incorporation in "integrated designs" was encouraged in the "American National Standard Practice for Office Lighting," ANS A132.1-1973.[4]

1/ "GSA Use of New Construction Concepts ...," p. 44.

2/ James King, "GSA's Experience [with non-uniform illumination], Lighting Design and Application, Vol. 6, No. 1, January 1976, pp. 52-56. In all, three million fluorescent lamps were removed or deenergized in 10,000 buildings, requiring 300,000 man hours. Annual savings were 7 percent of total energy costs.

3/ "IES Approved Guide for the Photometric and Thermal Testing of Air Cooled Heat Transfer Luminaires," Journal of the IES (October 1978), p. 57.

4/ The standard, a forward and four appendices (including one on measurement) appeared in the Journal of the IES, Vol. 3, No. 1, (October 1973), pp. 3-40.

But, as sections 3.2 through 3.5 indicate, the integrated package was not uniformly successful in its initial applications. Furthermore, changes in later performance specifications and also for reasons beyond the conditions listed in the Peach Books, the integrated HVAC-luminance-fire protection package never survived after the series I procurements. Take the Peach Book changes first.

GSA/PBS adoption of changes spreading through the Nation's lighting design community (described in section 2.3.1) and GSA/PBS' commissioning a new approach to acoustical design for speech privacy (described in section 3.7.4.3) were incorporated in the Peach Book's Second (June 1973) and Third (November 1975) Editions. The test methods associated with these changes had the effect of penalizing the series I integrated package's unbroken expanse of hard-surfaced prismatic lens geometry in the plane of the finished ceiling. That feature resulted in a reflecting plane relatively close to the acoustical sources used in field and laboratory testing to the SPP criteria.

But the initial applications were not fully successful for reasons beyond the control of the package's designers and fabricators: the reason was a sharp departure in operating practices induced by government-wide responses to rising energy costs described more fully in section 2.2. The integral package was a closely balanced system that was totally upset when temperature set-back rules were enforced on building operators.

The technical elegance of the integral package lay in its incorporation of the principles of passive, low-energy engineering design and the use of natural thermodynamic and thermophysical principles of heating and cooling. Specifically, the package used a passive system of inducing room air and blending it with conditioned air by aspiration, a natural phenomenon. But induction by aspiration is not precisely controllable. So when local energy management became a more prominent concern of building design and operations, variable air volume systems tied to local fan coil units were introduced in series II and III. In short, an active system, more closely controllable, was substituted for a passive one.

The ultimate indicator of the integral package's failed promise is that its principal inventor, Gershon Meckler, no longer advocates or even publicizes its use. This tacit admission is inferred from the integral package's total absence in Mr. Meckler's 42 page discussion of "integrated systems design" as a means of producing effective office environments.[1] The book in which this discussion appears represents a consolidation of the shifts in architectural engineering thought accelerated by the BSP experience. Several of its contributors either participated directly in, or incorporated technical materials initially prepared in response to, the BSP procurements. As if to underscore the failure of the integral package to further diffuse through the industry, the Harris book itself

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1/ "HVAC," comprising chapter 4 of David A. Harris et al., Planning and Designing The Office Environment, pp. 118-159.

treats "HVAC," "Lighting," and "Fire Safety" -- the three principal constituents of the integral package -- as separate chapters by individual authors.

3.7.5.6 Structure

No correspondent contacted by this project suggested that the structural subsystem portion of the performance specification yielded a technical or organizational innovation; nor does it seem, in retrospect, that a breakthrough was even remotely anticipated. Why, then was the structural system even included in the "seven by seven" performance matrix of building attributes and elements. The main reason seems to have been "structural" in the organizational sense of that term. The following are the condensed comments of several respondents:

- Structure was needed within the "System" to provide dimensional control and modularity;

- Its the great integrator of architectural space and other technologies, notably electrical and HVAC distribution;

- Structure is too large a cost item to leave out a procurement document, which is, basically, what the Peach Book was;

- It should've been kept out-of-system and made a "given" for each vendor. As it was, nothing could be done with the out of system portion of the work until the in-system (including structure) was far enough along. That made for a longer running project.

- The Government sought a diversity of responses and tried to write a "spec" that wouldn't prematurely eliminate any single class of structural solutions. So it kept "structure" in.[1]

3.7.5.7 Heating, Ventilating, Air Conditioning (HVAC)

As sections 3.2 and 3.3 reveal, HVAC performance as indicated by NBS air movement and temperature measurements in six BSP buildings was only marginally acceptable. Moreover, the evaluations reported by the GAO report fairly widespread dissatisfaction with this aspect of building performance.[2]

1/ As it turned out, three of the initial nine series I technical proposals (Step-One of the Two-Step Method) were for concrete structural systems. "Winner May Be Loser in SSA Project Competition," Building Design and Construction, October 1972. None of the three reached the bid phase (Step-Two of the Two-Step Method) of series I. No concrete systems were offered in series II and series III.

The high cost of entry also affected the rate of submissions, particularly from the smaller entities in the building community. See NBSIR 83-2662, p. 36.

2/ "GSA Use of New Construction Concepts ...," pp. 40-42.

What is not clear, however, is whether or not this performance is distinctive to the BSP building or whether users of all types of modern office buildings -- and not just "system" buildings -- register the same degree of dissatisfaction with performance. Mechanical system difficulties were noted in a published evaluation of the conventionally-built Ann Arbor (Michigan) Federal Building.[1] The HVAC system was the "major cause for complaints by agencies and individuals" in the conventionally-built Richard H. Poff Courthouse and Federal Building in Roanoke, VA, according to NBS researchers.[2] Is there evidence of similar dissatisfaction with thermal comfort performance of new buildings for private sector use as well? The relative performance in the Federal buildings -- whether built conventionally or by "systems methods -- cannot be established until that question is answered.

3.7.5.8 Electrical Distribution

Wiring for electrical power, telephone, and electronic signals, was distributed in the In-System portions of the BSP buildings through troughs or corrugations in the metal floor deck that, with its concrete overlay, doubled as a structural element. The underfloor raceways are spaced 5 feet apart. Access to the electrical service is through preset inserts in the raceway's top plate at 5-foot intervals; the insert cover plate is removed without special tools, requiring only a hammer-tap. Sixty four thousand such inserts are uniformly distributed through the 1,000,000-plus square feet of in-system office space in the series I procurement. This density of electrical availability may have been the BSP's significant initial contribution to office building design. At least one systems consultant expressed reservations about the near-universal availability of electrical service stipulated by the Peach Book for the In-System spaces and compared it to what the developer in the private sector would've done, faced with servicing tenants in a speculative office building:

> Well, that hardware is in [under the floor and] every 5 feet you've got one of those preset inserts, and that's terribly expensive. Now, I have a very large client who does [speculative] office buildings. He says, "Forget flexibility, forget preset inserts, forget all of that nonsense."
>
> You know, if that owner drills a hole through a floor and starts pulling wire, he can serve his tenant. Now, it depends on how he evaluates cost. He passes those on, of course, to his tenant, and so he absolutely is not going to spend any first costs for that. But the problem is I don't think GSA knows, really, how often they do move those [deck-mounted electrical and communications outlets]. My guess it that GSA is buying an awful lot of hardware -- those things every 5 feet and so on. They're buying a lot

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1/ Rober W. Marans and Kent F. Spreckelmeyer, Evaluating Built Environments: A Behavioral Approach, Ann Arbor: University of Michigan, 1981, p. 199.

2/ Jacqueline Elder, George E. Turner, and Arthur Rubin, Post-Occupancy Evaluation: A Case Study of the Evaluation Process, NBSIR 79-1780, National Bureau of Standards, Washington, DC, 1979, p. 37.

of redundant systems within the building that are never going to pay for themselves.

Figure 3.1 and the associated commentary on the "application" phase of the BSP innovations indicate that part of this prediction has proved true for the 3 to 8 years that the BSP buildings have been occupied; namely, the rates of change experienced in the BSP interiors is far less than was anticipated. But the second matter, the cost-effectiveness of GSA/PBS's decision on the method and availability of electrical distribution is beyond the scope of the current project and remains, at this point, a prediction neither confirmed nor denied by subsequent events.

The "information" and "diffusion" effects of the BSP's electrical distribution innovations are discussed in section 3.7.5.4 which relates how the effects of the initial GSA/PBS procurement ramified through the portion of the building community that supplies electrical products.

3.7.5.9 Luminaires

BSP lighting developments were modestly successful when measured by "application" criteria but were enormously successful measured by their "information" and "diffusion" effects. Field data summarized in section 3.4 and in figures 15 and 16 indicate lighting quality at or near the levels specified in PB:2 and PB:3 (PB1:R specified lighting quantity only). As was mentioned in section 2.3, some of the weakness in lighting performance may be attributable to the instabilities inherent in the lighting measurement equipment itself. But there is no mistaking the impact of the BSP procurement widening the awareness of Equivalent Sphere Illumination (ESI) as a method for lighting analysis and design and the world-wide marketing of a line of luminaires first developed expressly for the BSP procurements.

As a concept, ESI had been "around" for several years before GSA/PBS adopted the ESI approach to lighting specification in PB:2. GSA/PBS retained the services of a lighting consultant to operationalize some more general but computationally protracted ESI ideas that were then "in the air" but had not as yet been reduced to a standard practice, incorporating objective, repeatable, testable methods. In a manner analogous to its commissioning Geiger-Hamme to develop the SPP acoustical testing method (described in section 2.4.1), GSA commissioned lighting consultant William Jones to operationalize ESI.

The very act of specifying the lighting attributes of the prospective office spaces had achieved an "information" success in the technical discussion it stimulated. The information success went further: it stimulated the development of instruments for the field measurement of ESI in the US and in Sweden. Said one participant who was a consultant to GSA/PBS:

> I'm still convinced today that since this funny ESI thing we came up with all kinds of people have been out inventing meters. Every 6 months we see a new meter to measure ESI, and each is a little better than the last one. If someone hadn't started doing that stuff back in the second edition of the Peach Book and Bill Jones invented that

method for us, there wouldn't be guys out there inventing meters right now.

The diffusion success of the luminaire developed for the BSP Series II and Series III procurements is clear from examining the sales records of its designer-manufacturer. Moreover, the technical sales literature explicitly traces the origins of the unit's design as a response to the GSA/PBS lighting performance specification and mentions the BSP contract award for the 42,390 fixtures in series II and 2,607 fixtures in series III structures.

This low-brightness, high-performance luminaire incorporating baffle/reflectors whose (photometrically) parabolic shapes produce a bat-wing distribution of luminous flux is now marketed worldwide, both alone and in conjunction with proprietary integrated ceiling systems. Overseas sales are conducted through licensing agreements with companies in Japan, West Germany, and Canada. Licensing agreements with firms in other countries are being negotiated. Clearly, the BSP luminaire innovation enjoyed significant diffusion success.

3.7.5.10 Finished Floor

When asked if there was one area where the BSP's performance approach never "took", where reliable tests were not forthcoming or where products did not improve, GSA professional staffers, BSP designers and systems consultants separately retorted with an unequivocal "Yes: Flooring!" Remarked one participant:

> We, finally, in the third edition, just practically told vendors to get a nylon carpet. We couldn't devise tests so the whole [flooring specification] is very prescriptive the whole way through all three Peach Books.

Since no technical uncertainties were resolved, the finished floor procurement might be considered an information failure. On the other hand, since a competent, responsible decision could be made about finished flooring, it might be considered an information success (using these terms as defined in section 6.3 of NBSIR 83-2662). Neither case, however, justifies declaring the finished floor subsystem innovative. A tried and true technology was used: 18 inch square carpet tiles attached with non-setting adhesive (for quick access to the flush, deck-mounted preset inserts to the electrical raceways described in section 3.7.5.8). Using a well-known method assured application success in the six BSP buildings. Since no innovative technology was applied, its diffusion success is a moot point.

3.7.5.11 Finished Ceiling

The ceiling plane has drawn increased attention from the building community because of the increased use of open plan office layouts. The ceiling plane is now required to perform acoustically in a manner that will afford speech privacy to the space's occupants.[1] The BSP exemplifies this trend and the ceiling subsystem innovations developed during the BSP have ramified through the wider building community.

The information success may be gauged by the number of ceiling subsystem elements that came forward to meet the Peach Book criteria. Manufacturers, in the words of one successful vendor, "re-engineered some existing acoustical ceiling products to achieve the NRC of 85 felt necessary to meet the [Speech Privacy Potential] tests" of the large procurement.[2] (Owens-Corning won the procurement award for Series I and II; Armstrong, for Series III.)

Associated with the ceiling panels were the background masking sound systems incorporated into all 2.4 million square feet of ceiling installed in the six BSP buildings. That the installation was successful is clear from the acoustical data presented in section 3.5 and figures 17 and 18.

Diffusion success may be gauged by the fact that the "integrated ceiling background (ICB)" was spun-off from the set of seven integrated subsystems of the Peach Book procurement and is now offered as a "stand alone" specification widely used by both GSA/PBS and whose use is further encouraged by the Construction Research Council. A former GSA/PBS staff member estimated that the Government installs 5,000,000 to 6,000,000 square feet of ICB -- much of it in retrofit situations.[3] But government buildings are by no means the only place where ICB's are being installed. A large Central Engineering building at the headquarters of the 3M Company in Saint Paul, MN, was among the first users of the Construction Research Council's (CRC) performance specifications for ceiling systems incorporating ICB.[4]

1/ Richard Rush, "Technics: Suspended Ceiling Systems," Progressive Architecture, September 1980, p. 220.

2/ The statement could be misinterpreted since neither of PBS test methods addressed NRC. While it may be true that products meeting the PBS requirements may also attain an NRC of 85, it was not a Peach Book requirement. Conversely, there is no assurance that a ceiling product that does achieve an NRC of 85 will meet the SPP requirement.

3/ Remarks of John Tato at a May 16, 1978 roundtable discussion sponsored by Architectural Record and reported in its Mid-August, 1978 issue, p. 100.

4/ Richard Rush, "Technics: ...," p. 224, 226. The CRC is described in section 4.3.

3.7.5.2 Space Dividers

Table 3.1 indicates and section 3.6 discusses the application success of the space division subsystems at the BSP: state-of-the art[1] rigid, moveable, full height opaque and transparent/translucent panels and associated doors, frames, hardware, and door stops used for the floor-to-ceiling walls creating compartmented offices and conference rooms and for separating circulation space from spaces assigned to various programmatic functions. More innovative, however, was the space division subsystem developed for BSP's "open plan" approach to interior design for Federal offices. There were partial height screens (the Peach Book:3 specified 72" and 60" heights, for instance) in modules of varying width.

These screens were developed and installed as part of the initial procurements in the mid-1970's thus qualifying them for application success. Several years later, Tibbet, Incorporated purchased the sound divider and wall panel operations from the series I and series II contractor and is now marketing the panels and dividers internationally. Their annual gross sales exceed 20 percent. That BSP stimulated development of a product line that now is available worldwide is, surely, a significant diffusion success.

1/ A building products marketing consultant who spent years in the space division branch of the industry acknowledged to this project that the BSP procurements consolidated earlier innovations in moveable partition systems rather than advance novel concepts.

4. FINDINGS AND DISCUSSION

4.1 PERFORMANCE OF SELECTED PHYSICAL SUBSYSTEMS

Measurements presented in section 3 speak for themselves: buildings generally in control, at or near specified levels of performance. Neither location with BSP buildings--at the perimeter or within the interiors zones--nor type of office arrangement--whether compartmented, screened or pool--affected measured performance: very little variance was found among these subdivisions and none of it of statistical significance. The only clear trend was that, except for lighting, performance improved uniformly through the life of the BSP.

The ground rules for the present study precluded soliciting responses directly from the office workers and their managers and other building users. Nevertheless, workers and managers in all six buildings made spontaneous comments to the NBS staff measuring the building. These comments were overwhelmingly negative and ranged from complaints of inconvenienced to perceived threats to vision and general health: "radiation", "lack of air", and "glare" were the most frequently remarked threats to safety and health. Managers in one building complained that "people didn't know how to dress for work because of the day to day (as opposed to seasonal) swings in ambient temperature." These remarks suggest that the specific performance criteria may need to be reconsidered in future building procurements.

4.2 BUILDING PERFORMANCE IS A PRODUCT OF PHYSICAL DESIGN AND MANAGEMENT PRACTICES

The six BSP buildings are performing at nearly the levels specified in the several editions of the Peach Book. They are generally "in control," although building operating practices -- some taken in response to directives from GSA-wide management -- appear to have overridden the specific performance targets stipulated in the Peach Books. Building operations staff admitted to the author that they altered air-handling routines in order to reduce energy use even though this resulted in near-stagnation conditions in parts of the BSP buildings.

The hardware subsystem's performance by itself, however, continually improved and each succeeding series of the BSP came closer to meeting the specific Peach Book targets than did the buildings of the earlier series. This evidence of cumulative improvement is conspicuous in the measurements of air movement summarized in figure 6. But, despite continual building-to-building, series-to-series improvement, air movement still hovered at or below the lower limit (20 ft/min or 0.1 m/s) specified in all three editions of the Peach Book.

Another case of conspicuous differences between Peach Book intentions and operating practices occurred in the uses to which acoustical elements were put. The GSA/PBS assigned to the movable, shoulder-high, space-dividing screens specific functions in enhancing the acoustical environment of the Federal office. This assignment was carried out along three fronts: 1) through the Speech Privacy Potential method of specifying acoustical performance in the Peach Book itself; 2) in the form of PBS Test Methods PBS-C.1 and C.2 for use in other than BSP buildings; and 3) as instructions and guidance to the tenant agency users and managers of Federal office buildings as in the 87 page illustrated GSA/PBS booklet, Office Acoustics: A Users and Manager Guide, issued in April 1979, as the BSP buildings were being initially occupied.

Clear advice to the contrary, notwithstanding, the screens, which could be moved without special tools, were found used as sunscreens on some western and southern exposed BSP floors. Instead of using the moveable screens for their intended use -- the wide dispersion of acoustical absorbent -- tenant agency managers hoarded the acoustical screens and diverted them to the provision of visual isolation for higher level officials, deploying them as defilade, defined by the dictionary as a "military fortification arranged to protect against fire of observation from a given point."

Despite this "incorrect" deployment of acoustical absorption, however, the BSP buildings achieved an acceptable acoustical environment. This is clear from figures 17 and 18. This leads to one of two interpretations, the BSP acoustical designs were robust enough to achieve required performance even when incorrectly implemented. Viewed negatively, the BSP acoustical designs incorporated redundant absorption, redundancy achieved at costs higher than what the most efficient design would require.

But what is the efficient solution in this case? GSA prides itself on professional building management by the PBS staff. But GSA has no direct control over the facilities management attitudes or expertise of the tenant agencies. Should GSA buildings be outfitted as systems designed by technical specialists to be run by management generalists? This question of excess capacity or engineering redundancy needs to be examined in the light of controlling building costs while serving a diversity of agency management styles. To what extent should building design enable Federal users -- managers, staff, and visitors -- to adapt their surroundings to their own needs? And at what price is that latitude too costly for the Federal Government? How many of these decisions should be left for the occupants and how many occupant decisions should GSA/PBS -- seeking economic efficiency -- preempt?

Lighting was another area where variations in local operating practices initiated the designer's intent. This occurred in two ways: maintenance practices and work station arrangements. While the overall lighting performance for the most-part met Peach Book criteria, there were occassional lapses in the maintenance regime. A singular lapse was encountered, however, when in one randomly selected bay one third of the luminaires malfunctioned.

Quality lighting aims to reduce veiling reflections on the visual task. This is usually accomplished by diminishing the light from in front of the viewer and increasing it from the side. Consequently work station orientation with respect to the luminaires is an important factor in assuring an effective visual environment. The luminaires in the six BSP buildings are in fixed locations, but the work stations are oriented by the tenant agency managers at each site. These work station orientations varied from building to building and from floor to floor within buildings. In some cases, desks, for example, were aligned parallel with the longer dimension of the luminaires (which themselves were in a staggered row configuration); in other cases, with the shorter dimension. In the smallest number of cases, desks were set on a 45° bias from the long dimension direction of the luminaires. Moreover, some desks were placed directly under luminaires while others were located under the ceiling between luminaires. What arrangements provide the best seeing conditions?

The point of this review is to indicate how much discretion over the effective use of buildings is in the hands of the occupants who may make uninformed choices whose effect might vitiate the best intentions of the designers and the professional building managers. This is not an oddity, occurring only now and then. This disjoint in environmental management occurs often and needs to be addressed if buildings are to be more effective workplaces.

4.3 WIDER EFFECTS OF THE BSP: NEW PERCEPTIONS, NEW INSTITUTIONS

This section amplifies two more subtle effects of the BSP that may ultimately be more pervasive in their influence than the diffusion of the eleven specific hardware or software innovations presented in section 3.7.5. The first was the formation of the Construction Research Council (CRC), a private, nonprofit association to improve the building process through continued application of advanced technologies and management concepts.[1] Many CRC members and most of its leaders achieved national prominence during their participation in the BSP. The institutional building owners, the building product manufacturer and design and consulting firms associated with CRC continue procurement programs using many of the methods pioneered in the Peach Books, working to improve the usefulness of the performance approach, and extending its other building types.

The new perception that BSP brought to the building community was an appreciation of the composition of the costs of occupying an office building, a composition summarized as the "2 percent, 6 percent, 92 percent" breakdown of the costs, respectively, of designing and building, operating and maintaining and paying the salaries of building occupants over the building's 40-year life cycle.

Analyzing building cost data in this way was novel in 1970, when PB:1 presented it for the first time. In the years since, producers of building products and providers of building services have used this analysis in promotional literature.[2] Public agencies have recast their discussions of building projects in these terms, most conspicuously the California Office of the State Architect which in a 1976 publication developed a building effectiveness valuation procedure and acknowledged the NBS analysis developed earlier for use in the Peach Books.

1/ CRC, Suite 1040, 1800 M St., N.W. Washington, D.C. 20036.

2/ Some examples: Steelcase, Incorporated; American Society of Civil Engineers; General Electric Lamp Marketing Department.

The California State Architect's Office, in demonstrating a case of valuing buildings not as passive absorbers of capital but as operating entities, argued that a better working environment that improved worker effectiveness by only 6-1/2 percent would be cost-effective even if it quadrupled the cost of the building![1]

Similar arguments have been made before committees of the U.S. Congress and some of them have referred expressly to the NBS analysis that appeared originally in the Peach Books.[2]

National Endowment for the Arts Chairman Livingston L. Biddle, in an October 15, 1979, statement to the Senate Committee on Environment and Public Works hearing regarding compensation for designers, referred to the 2 percent, 6 percent, 92 percent relationship of costs reported to GSA by NBS. Said Mr. Biddle:

> Seen in this light, arguments about whether architectural commissions should be limited to 6 percent or 10 percent of capital costs, when these same commissions measured against the total life cycle costs are fractions of a percent, appear to suggest that we should be putting more resources in the design of our public buildings, rather than less.

The importance of bringing to the building community and to society at large an important new conception of the ultimate benefits and costs of a building project can hardly be exaggerated. This is because large changes in the physical world are usually preceded by careful thought--particularly an action as lasting as the erection of a building. And thinking about a subject is enormously influenced by the initial conceptualization of the problem at hand. For public actions, actions by governments, this is especially true because those conceptualizations must be shared by many and diverse constituencies before action is taken. Consequently, a truer perception of building benefits and costs promises to improve the level of public discussion about what an optimal public investment in buildings would be. These very early studies, as conveyed to the building community in the early Peach Books, are still altering perceptions about buildings. It is truly ironic that the BSP's longest lasting and furthest diffused contribution to the wider building community may not be the 4 million gross square feet of construction or the 2.4 million square feet of "systems building," but rather a new view of how buildings should be perceived and, ultimately, valued.

1/ California Office of the State Architect, Building Value Energy Design Guidelines for State Buildings (Sacramento, January 1976, p. 7). Emphasis in the original.

2/ Congressional Record - Senate for December 5, 1979, remarks of Senator Moynihan in support of S.2080 (which later passed the Senate by a vote of 71-8), p. S17858.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

This section is organized to accord with section 1.2 which summarized the objectives of the documentation and assessment project. These recommendations are based on the professional judgement of the author as that judgement was informed by the field assessment described in this report and by wide discussion with participants in and knowledgeable observers of the BSP.

5.2 BUILDING TECHNOLOGY AND PROCUREMENT ISSUES

Section 4 indicates that GSA/PBS was able to use then-current technology and then-advanced procurement methods to achieve the building performance levels it specified. Whether or not those levels are achievable using other, more conventional technologies is not known because of the earlier decision to remove from the study comparisons between the BSP procurements and the conventionally-built office buildings then being designed and erected. There is no basis for objective comparisons. But even within the confines of the BSP itself there is enough experience to suggest improvements. Indeed, some of the successful participants offered such suggestions while the BSP itself was still in progress. Specific items deserving further consideration are:

5.2.1 Flexibility

The enormous flexibility available to BSP building occupants is, as yet, not exploited. The nearly universally-available underfloor appurtenances for electrical power distribution for telephone and signal communciation, and for computational capacity lies largely dormant beneath the BSP flooring. To some extent this lack of use has been attributed to the fact that the principal BSP tenant -- the Social Security Administration -- operates in a very stable routine with relatively little need for rapid and/or frequent change. But even the Norfolk building, the only BSP structure built as a multi-tenanted, general-purpose office building, showed a low utilization of its flexible features.

A large study of American office use recently reported that one-third of office workers are moved, on average, twice each year but that only about one-tenth of them move between three and six times each year.[1] Put another way: only a small fraction of the office force is moved about, but they're almost always on the move. The majority of office workers stay put during the year. This finding -- coupled with the data presented in table 3.1 -- brings into question the Peach Book goal of facilitating moves by anyone anywhere in a BSP building. The Peach Book's goal of flexibility may still not be in error, however, because the Series I BSP buildings are still only one-fifth of the way through their

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1/ BOSTI, The Impact of Office Environment on Productivity and Quality of Working Life: Comprehensive Findings, pp. 26 and 231-237. Available from BOSTI, 1479 Hertel Avenue, Buffalo, NY, 14216.

planned life-cycle. Nevertheless, the goal of flexibility universally available within the BSP structures should be reconsidered.

5.2.2 Microzonation

The Peach Books specified a "universal" availability of electrical power and communcations access in uniformly conditioned office interiors. Section 3 demonstrates that uniform conditions were achieved. But as described in section 3.3, the piecemeal introduction of advanced office technology equipment, while electronically serviceable through the underfloor duct systems, is introducing large cooling loads at isolated points throughout the BSP interiors, causing local thermal discomfort. Tenant agencies installed portable electric fans to improve working conditions.

The philosophy that dominated environmental conditioning design in the 1970's -- traceable to aesthetic theories of the 1920's -- was to treat spaces uniformly for heating and cooling. This was a natural occurrence since the principal sources of heat at that time were the occupants and occasional equipment, generating a combined load of 1.7 Btu/sq. ft, and the uniformly distributed 100 foot-candles of illuminance at the desk top that generated a uniformly distributed thermal load of 4.0 Btu/sq. ft. But because of the combined effects of more efficient lamp and luminaire design, the growing use of task lighting, and new understanding of human visual response leading to revised lighting standards, the heat contribution of lighting has fallen sharply. This heat load from lighting, while large, is no longer the driving factor in HVAC design; moreover, it is less likely to be a uniformly distributed load. U.S. experts now estimate that the proliferation of electronic office devices will, with their operators, generate 18.0 Btu/sq. ft. and do so in a non-uniform pattern. This latter finding has immediate implications for building design and space management and suggests that the Peach Books performance specification summarized in table 2.2 be altered to create much smaller zones of highly changeable service.

Recent British investigations of the impact of information technology on office design also forecast that increased use of heat-generating electronic equipment will create a need for additional cooling <u>at specific points</u>.[1] Whether uniformly distributed cooling (the approach embodied in past Peach Books) or point cooling is more effective and economical depends, of course, on the detailed architectural judgements (relating to building function) and engineering analyses (relating to building physics) of particular cases. But the ideal of uniformly conditioned, universally flexible space needs seriously to be reexamined to better accommodate advanced office technology.

1/ Personal Communication from Francis Duffy, principal author of <u>The Orbit Study: Information Technology and Office Design</u> available from DEGW, 8-9 Bulstrode Place, Marylebone Lane, London, WIM 5FW.

5.2.3 Prequalification

GSA/PBS sought to shorten radically the time needed to bring new buildings on stream by "prequalifying" building systems in advance of procurements for specific buildings.[1] The Series III was to have been the first of the prequalified systems buildings. But in the face of rapid change of office functions and the burgeoning information technologies to service them, prequalification seems ill-advised and should not be further pursued because it may freeze technologies prematurely. This already happened during the life of the BSP: section 3.7.5.4 reported that technological developments outran the Peach Book criteria even while innovative assemblies were being developed. So that a separation in time between an assembly's qualification and its use could result in prematurely obsolete buildings. Moreover, recent analyses suggest that the costly delays affecting Federal building procurements issue from the "regulation and mandates that attend the expenditures of federal monies"[2] rather than the technique of design and construction and those administrative procedures might be a more significant opportunity for saving time.

There is evidence that other elements of the building community are withdrawing from the prequalification approach. Institutional owners and suppliers of building products and services, comprising the Construction Research Council, have voiced misgivings over the threat of legal and financial liability of the qualifying entity should the prequalified items fail to perform as qualified.[3] The CRC, an early advocate of both the performance approach to procurement specifications and its extension into prequalification of innovative technologies, is now considering a "pretesting" approach in which producers submit to a central repository quantitative and qualititative test data stating maximum and minimum levels of performance and giving evidence that those levels were achieved. Owners and specifiers would then choose. In this approach, test results, not evaluations, would be deposited, reducing the threat of legal liability.

Congress created the National Institute of Building Sciences (NIBS) in 1974 (PL 93-383) and specifically authorized NIBS to carryout "[e]valuation and prequalification of existing and new building technology ..." In partial response to that mandate, NIBS -- with fundings from several Federal agencies -- has undertaken a documentation and assessment of regulatory and non-regulatory

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1/ This approach is further described in NBSIR 83-2662, section 2.4.

2/ Congressional Budget Office, The Federal Buildings Program: Authorization and Budgetary Alternatives, June 1983, The General Accounting Office has made similar comments for many years.

3/ This was remarked by several participants at CRC's November 10, 1983 meeting.

product approval practices. GSA/PBS should monitor this effort with a view to adapting its findings to GSA/PBS's prequalification decision.[1]

5.2.4 Procurement by Prototype

While the prequalification of technologies for use in future seems problematic, GSA/PBS should continue the practice, undertaken in each of the BSP series, of building full scale prototype modules of integrated building systems before making final choices among candidate designs for large procurements. This practice -- which is a workable element of the performance approach -- should continue until better analytical methods are devised for use in predicting performance of architectural and environmental control designs. Since these better analytic methods lie far in the future, and better predictive tools are even further away, interim solutions for reducing technological unknowns should be pursued via wider use of prototypes.

Risks and uncertainties attend every effort to innovate. Well-developed analysis methods and simulation techniques have sharply reduced these risks and uncertainties in the design and use of structural and envelope systems, but the areas of spatial perception, lighting and acoustics are hard to predict at the scale of the typical office. Moreover, the increased use of electronic equipment and systems furniture in Federal offices make suspect any prediction methods devised originally for uniformly-conditioned spaces. The criticism that prototyping candidate designs adds to overall program length and cost needs to be examined, of course, but there are two responses to this. First, a recent Rand Corporation report to the Air Force evaluated engineering prototype programs costing one to ten percent of the total weapons acquisition budget and suggested that "prototyped programs pay for themselves and do not lengthen the total time of the acquisition process."[2] Secondly, there are other creative uses for completed prototypes that provide considerable salvage value. The most creative use of the BSP prototypes, for instance, was the initial supplier's incorporation of its series III prototype into a suburban Norfolk, VA industrial park being developed at the time of the GSA/PBS procurement. The former Series III prototype still operates there as a small office building!

A further advantage of prototyping is that it enables the procurement to proceed efficiently from the standpoint of reducing the paper work burden on system suppliers and government purchasers, thus providing a technical solution of the administrative difficulties of Federal building procurement criticized in the past by the General Accounting Office and by GSA's own internal professional staff and more recently by the President's Private Sector Survey on Cost

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1/ While it is true that the several model building code organizations issue "product research reports" on innovative technology, those reports are intended to inform regulatory decisions -- dealing largely with matters of health and safety -- as contrasted with the procurement decisions -- usually concerned with serviceability and economy -- of interest to GSA/PBS.

2/ G.K. Smith, _et al._, _The Use of Prototypes in Weapon System Development_ (Santa Monica: Rand, March 1981 (R-2345-AF).

Control (the Grace Commission). Without use of prototypes, detailed contracts and other construction documents must be devised and administered fairly. This requires, often, the build-up of program office staffs. Use of prototypes, on the other hand, relies on competition to ensure that several contractors perform effectively. In other words, GSA/PBS should create opportunities for exploiting the competitive environment as a substitute for extensive administrative controls over designers and contractors. (Recall that many prospective vendors were deterred from entering the BSP by the prospect of burdensome administrative procedures and the costs of doing business with the government.[1])

The use of prototype modules is especially recommended in cases where several innovative technologies are emerging in previously untried combinations. This is manifestly the case in the "office of the future" situation confronting GSA/PBS in which the electronic, ergonomic, and environmental attributes of the novel products and systems are converging for the first time. No analytic methods exist to enable a designer to predict with confidence what will happen nor will straightline extrapolations from experience with any single item be a helpful guide. Reducing this uncertainty is the main benefit of procurement by prototype. But it may have another advantage: one great lesson of the intensely competitive computer industry is that efficiencies resulting from a competitive environment could exceed the direct costs of supporting groups developing an alternate method for achieving the same internal corporate objectives.[2] This expanded use of procurement by prototype is the report's principal recommendation for an alternative building procurement method.

5.2.5 Issues Needing Further Research

5.2.5.1 Occupancy Costs

The 2 percent, 6 percent, 92 percent relation of office occupancy costs was reasonable for the time the estimate was made, 1970. But that relation should be reexamined in the light of these changes: the continuing effects of higher energy costs; the emergence of the "high tech" office; and the changing nature of the Federal work force as office functions shift from sheltering routine clerical production to more highly differentiated, knowledge-based decisionmaking.

Valuable as it has been in drawing attention to the long-run costs of conducting operations in office buildings, the cited 2 percent, 6 percent, 92 percent, relation may not reflect today's situation. Consequently, further reliance on 2 percent, 6 percent, 92 percent might lead to sub-optimal allocation of Federal capital resources. The higher cost of energy may mean that the 6 percent of total costs assigned to operations may be too low. In addition, the labor-intensiveness of building maintenance also suggests that the 6 percent share

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1/ NBSIR 82-2662, section 6.2.

2/ How this intra-firm competition occurs in the computer industry is vividly recounted in chapter 6 of Tracy Kidder's, The Soul of a New Machine, (Boston: Little, Brown, 1981).

may not reflect rising labor costs. On the other hand, the salary and skill composition of the Federal workforce is certainly not what it was in 1970. But what is it and has that change made the 92 percent obsolete? Employee characteristics vary from agency to agency and so do the salaries paid. For instance, an analysis of the (non-BSP) Ann Arbor Federal Building found that professional-technical employees comprised 80 percent of the staff of one agency but only 50 percent of occupants of the entire building.[1] Thus the 92 percent figure may be true for only a certain range of agencies. Offsetting this is the higher cost of designing and building-in suitable control devices to condition the environment for sensitive electronic equipment, and this would affect the 2 percent figure. In short, this important perception about the full cost of occupying buildings needs to be kept technologically current and flexible enough to accommodate the variety of Federal office buildings. Other Federal agencies might be encouraged to develop counterpart data for building types associated with their missions; e.g., the Department of Health and Human Services and the Veterans Administration for hospitals and the Department of Education for school buildings, to name but two.

5.2.5.2 Unobtrusive Measurement Methods and Instruments for Field Use

This project found few choices of instruments and methods for measuring physical attributes of building performance in a manner that wouldn't disrupt building operations or agency functioning. More real-time building diagnostic tools and methods are needed if the performance approach is to achieve its full potential in achieving more effective building procurement and operations.

Measuring illumination provided for visual tasks can only be done at night if the recommendations of the leading lighting technology group are followed. The valuable contribution of daylighting is thus systematically excluded although common sense (and most building occupants) suggests daylighting is now an important element of building satisfaction and its use is destined to grow. Photometers are sensitive to heat generated by their own electrical circuitry and can be used for only short periods to allow cooling off. Another instrument required a conventional screwdriver, a Phillips-head screwdriver and an Allen wrench merely to gain access to the battery pack! These are some of the shortcomings of the instrumentation available for field use. Little wonder that routine monitoring of the performance of existing building is rarely performed. Yet accurate and timely feedback is necessary for the continued improvement of professional practice in building design and operations.

Further work is needed on sampling methods for buildings. The present study is one of the few to employ an explicit spatial sampling strategy, but temporal sampling is at least as important. Each BSP building was measured over a three-day period during the 1982-83 heating season, almost always during working hours except for the nighttime lighting measurement. But with flex-time use growing

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1/ Robert W. Marans and Kent F. Spreckelmeyer, Evaluating Built Environments: A Behavorial Approach, (Ann Arbor, MI: University of Michigan, Institute for Social Research, 1981, table 3.1, p. 44.

considerations remain important for small buildings, (but not necessarily for interval-load dominated BSP buildings), then season-of-the-year sampling becomes important. But the building diagnostic literature is sparse on these matters and conceptual work should be organized now to make future empirical studies less costly and, most important, more accurate.

5.3 SUMMARY OF RECOMMENDATIONS

This project recommends to GSA/PBS the following actions:

- reconsider the economic and architectural benefits and costs of providing uniformly conditioned spaces with universally available services;

- do not resume the prequalification approach to evaluating innovative building technology without first reviewing the results of the forthcoming NIBS report and consulting with the CRC;

- explore use of prototype based procurements for Federal office interiors, especially where automated and electronically enhanced office functions are anticipated;

- reexamine the composition of occupancy costs with a view to supplementing the 1971-issued 2 percent, 6 percent, 92 percent relation with a relation firmly based in current and likely future experience;

- support industry-government-university efforts to improve the efficiency, accuracy, reliability and replicability of unobtrusive measurement methods and instruments for field use.

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This report assesses the General Services Administration/Public Buildings Service's (GSA/PBS) Building Systems Program (BSP) and recommends methods for furthering the program's objectives. Lighting, air movement and temperature, acoustics, and the flexibility of interior space division in the six buildings completed under the BSP are evaluated by comparing field measurements made in February-April 1982 with the performance specifications for those four attributes at the time of procurement. The wider effects of the BSP innovations on the building community are qualitatively evaluated.

By and large, GSA/PBS achieved the building performance levels it sought, but whether more conventional design and construction procurement methods would have met those levels at a lower life cost and in less time is not known, given the data available to use in the present study. Some of the specific technologies pioneered in the BSP procurements have diffused to the worldwide building community and over four million gross square feet of BSP offices are now occupied by 12,000 Federal workers. Yet, in spite of these successes, building industry participation diminished as the BSP continued. The lasting BSP contribution, however, may be in its furtherance of a novel and useful conceptualization of the stream of benefits and costs of a building project.

This report complements the project's initial report, Documentation and Assessment of the GSA/PBS Building Systems Program: Background and Research Plan (NBSIR 82-2662, February 1983), that traces the origins and conduct of the BSP from 1965 to 1980.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

building measurement; building systems; Federal buildings; field assessment; office buildings; performance specifications; post-occupancy evaluation; procurement; technical innovation.

13. AVAILABILITY

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