PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Recent Developments in Building Systems

H. B. Finger

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Recent developments in building systems

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The dynamic competition among innovative concepts, materials, methods and products that has characterized most consumer industries has not been fully effective in the business of housing. Although evolutionary progress has been made over the decades, the structure of the housing business, the existing institutions, the regulatory procedures and other factors have discouraged rather than encouraged modernization and improvement consistent with our overall technological, social, economic and political progress. The paper will describe the results that are being obtained in the United States from an overall approach aimed at overcoming these obstacles to more rapid modernization. This effort, under the title 'Operation Breakthrough', aims at encouraging a competition among ideas, methods, materials, and a restructuring of the regulatory and other elements of the housing business. The goal is improved housing for all of our people in a good living environment.

The paper describes changes that have already taken place in the building regulatory area. New approaches which are being taken by many of the States, as compared to the more traditional, local jurisdictional practice, and to some still existing State regulatory practices, are described. In addition, the paper describes the technological effort that is required to evaluate new ideas in building systems. The major point to be made in this connexion is that extensive testing, as well as research and development, is required to solve problems associated with new systems when they are designed to meet certain performance criteria. Established practices have the advantage of experience and past public and professional acceptance. The new systems must be encouraged in order to arrive at a position that can indeed be considered competitive with the traditional approaches.

Detailed technical analysis is indicating the problems that exist and that must be solved with a wide variety of technologies that have not yet been put into full practice in the United States. The result would be a fuller, more dynamic competition among a broader variety of building approaches.

But the emphasis is not on the buildings alone. Rather, it is on total community design and development. Mixed functions and mixed building types combined into a total residential community are also being carefully considered in their design. This part of the Operation Breakthrough programme is intended as a model for general urban growth patterns. Examples of the approaches being used in, and technical advances being tested for, Operation Breakthrough are presented.

I want to thank you for the high honour you have given me and all of those working on Operation Breakthrough in inviting me to this meeting of the Royal Society.

I want to preface my remarks by acknowledging the importance of the British and other European building systems that are in the Operation Breakthrough programme. In a real way, this is an international programme, one which encourages the advance of innovation and application of modern technology in the housing industry and which has chosen, as the subjects for demonstration, some systems from other countries in addition to our own.

Actually, very little of what we are doing involves basic research or totally new hardware technology. The programme will be a success, from the technology standpoint, if we facilitate the acceptance and use of that technology which currently exists, but has not yet found extensive use by the housing industry. The real objective is to overcome the barriers to advancement in the housing business. Sir Marice Laing has identified many of those that concern us as well as you.

In considering 'technology' in housing, we must view that term in broad definition as 'the sum of the ways in which any social group can provide itself with the material objects of their civilization'. Technology is not hardware, but *means* for providing material benefits to our society.

It is now thirty months since Operation Breakthrough was announced by Secretary George Romeny in meetings with labour, industry, professional groups, local and state officials. To many who are outside the programme, this has seemed like a long time. For those of us in the programme, the time has been very short and I suggest that the record of accomplishment will clearly demonstrate that the time has been well spent.

The stimulus this programme has provided to all sectors of the housing business and to state and local government officials and regulatory bodies is already a most significant and obvious measure of the success of Operation Breakthrough. The programme has encouraged improvement, stimulated change, made innovation respectable and acceptable to the American consumer and to all involved in housing. As a result of Breakthrough's encouragement, many companies are moving toward industrialization as they enter the housing business or as they expand their existing housing business. The overall result is that the entire housing business is changing more rapidly than it ever has; it will not be the same as it would have been had Breakthrough not been initiated.

More specifically, Breakthrough has already had major effects on many of the constraints that existed when the programme started.

(1) Twenty of our 50 states have passed mandatory state-wide industrialized housing laws or general purpose building codes. None were in effect before Breakthrough. These laws re-assert state authority in the building code area and stipulate that housing approved by the state must be accepted everywhere within the state. Such laws help industrialized housing and also provide a basis for extending state-wide authority for all housing. This addresses a problem (the thousands of local code variations) which does not exist in many European countries but which has traditionally been a major constraint in the United States.

(2) National building trade labour organizations have established labour agreements that encourage the production of housing in factories on an *industrialized* basis. These agreements provide for special factory wage levels instead of higher field wages; they provide for larger proportions of lower skilled workers, minority labour training opportunities, and also permit work and jurisdictional rules to facilitate efficient, industrial production.

(3) Transportation is a key linkage to wide markets for factory-produced housing. Operation Breakthrough has worked with other government agencies and with the transport industry to reduce truck tariffs, to reduce highway restraints and red tape, to interest railroads in long-range shipments at reasonable tariffs, to develop standardized new hardware and flatbeds made to handle housing components, and to investigate barge and even helicopter alternatives.

(4) Operation Breakthrough activities have already provided for familiarization of a large part of the Federal Government's H.U.D. mortgage insurance organization with the differences between innovative, industralized housing approaches and those that have been conventionally handled. As a result, changes have already been made in H.U.D. processing and regulations that recognize these differences and we have proposed other changes which are under consideration.

(5) Performance criteria for housing have been developed by the National Bureau of Standards and reviewed by the National Academies of Sciences and Engineering. These provide a new effective benchmark for design efforts and for evaluation of innovative technology and they provide a guide of good practice for improving code administration. Industry-wide comment had been solicited and will be considered in the continuing revisions of these guide criteria. (This will be discussed in more detail later.)

(6) All fifty states and many local communities have named special representatives for Operation Breakthrough. In this respect, Operation Breakthrough has been a pacesetter in involving and encouraging state participation in housing and community development activities.

(7) The criteria for participation in Breakthrough require special quality assurance programmes that are aimed at assuring a consistently high-quality product. This is essential in overcoming past impressions that 'prefab' housing was not of good quality.

(8) A wide spectrum of financial institutions have been exposed to industrialized housing through Operation Breakthrough. These include the Government National Mortgage Association, Federal National Mortgage Association, Federal Home Loan Bank Board, thirty to forty savings and loan institutions, ten to fifteen mortgage bankers, insurance companies, commercial banks, and state housing finance agencies.

(9) Operation Breakthrough has also provided leadership in the application of improved management systems in the industry, including construction project management techniques and also including the development and application of new, more refined cost controls and cost accounting systems that marry the most useful of field construction accounting to advanced factory production cost accounting.

(10) And finally, the most visible and most discussed part of Operation Breakthrough – its nine prototype sites and 22 housing systems – are well into production, construction and development.

These sites, though prototypes, should all be completed in less time than it normally takes the average developer to complete comparably sized projects. These prototype sites should provide a new model for residential communities including a variety of functions, a variety of housing types, and land use designs that preserve the environment and give full consideration for the living requirements of all people.

In addition to the 2938 prototype units to be built on these Breakthrough prototype sites, over 5000 units have already been processed for follow-on volume production. It is expected that by July 1972, 25000 units of Operation Breakthrough housing will have been processed for production. Those numbers are very large in comparison with the number of industrialized units produced in this country in recent years.

The American consumer appears not to accept and appreciate the benefits of industrialized housing. I believe we are truly overcoming past prejudice against 'prefabs' because of the quality requirements of Operation Breakthrough. But the Breakthrough sites will give the American public a way of judging these housing and community concepts.

These results, accomplished in only 30 months, indicate the changes taking place in the housing business that will not be reversed. This decade will see more rapid changes in housing than at any previous time. In my mind, 30 months is a remarkably short time to have made these achievements.

I would like to devote most of the remainder of this paper to two segments of the Operation Breakthrough programme – site planning and the technical effort in the development of the performance guide criteria. In addition, I will mention some further experiments on utility systems on our Breakthrough prototype sites.

1. Site planning†

The Breakthrough effort has focused our attention on the status of site planning and the physical and aesthetic qualities of residential communities. However, it should be noted in reviewing the physical aspects of residential communities we must be careful not to imply that good physical design alone will automatically result in a 'good, viable community'. Just as the bricks and mortar used to build the *house* does not in itself make a *home*, so the best designed site plan alone will not assure a long lasting viable community. Many elements are needed; well planned and aesthetically attractive structures; a site layout that is thoughtful, functionally sound, endowed with adequate landscape amenities and containing the needed outdoor spaces and facilities that the residents will need, in a proper spatial arrangement; adequate management and services for the residents; adequate maintenance and satisfaction of the requirement for security.

† I would like to emphasize the assistance of Milton R. Edelin of the Operation Breakthrough staff for this section.

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In the United States, an examination of the prevailing status of physical site planning indicates:

(1) The generally inadequate and poor quality of project planning.

(2) The past lack of emphasis on better planning of our residential communities.

(3) The lack of a systematic approach to site planning.

(4) The lack of generally acceptable 'norms', or credible criteria for site planning. This would address the way a site functions as well as the amenity level and people needs level at the site, and, the interrelationship of the space and uses on and off the site.

(5) The lack of sufficient evaluation of alternate approaches to land planning that would identify efficiencies and economies of various plans.

(6) The need to address better the before and after ecological impact upon natural and man-made environment.

(7) The lack of flexibility in our land use ordinances, and in many instances the requirements within these ordinances that prohibit and/or have a negative effect upon better planning and development.

I will briefly discuss these items by reviewing the Breakthrough experience to date.

(*a*) *Present poor quality of project planning*

Too often buildings are arranged in an arbitrary fashion. If existing topography and ecological factors and constraints are ignored, if views and hostile factors such as noise are not considered and if the land is stripped of vegetation, the result is not just bad site planning, it is no site planning at all.

For good plan development, there are various levels of design to be considered. First, there is the broad, distant, physical image, such as the Manhattan skyline, the Golden Gate Bridge against the variegated San Francisco skyline, or the spires of a cathedral rising above a village. At the other end of the spectrum, there are our intimate personal experiences which include our house and the project or neighbourhood in which it is located. It is at this scale that our Department of Housing and Urban Development might best be able to promote better design through the housing developments it insures and subsidizes.

Over the past few years, there has been an increase in housing provided under Federal subsidy programmes. Last year alone, over 400000 federally subsidized units were started. This represented 25% of the housing production so it is evident that leadership by the Department in the areas of superior housing design and better site planning would have a measurable impact on the whole industry and the consumer.

Instead of well-designed communities, much of our development is characterized by monotonous tracts. At the end of World War II, we launched into an era of producing communities with endless, uniform rows of little boxes (figure 1). Now, we usually put them on curving streets, but too many still have an equally unimaginative approach.

In our garden apartment and row house developments, including many of our subsidized developments, we permitted the land to be covered with buildings and pavement for automobiles (figure 2). The unimaginative schemes result in dreary living environments – totally lacking in areas for recreation and landscape amenities.

On the entry there are endless rows of buildings facing each other; to the rear, privacy and landscaping are replaced by clutter and an unattractive environment. Many projects lack any provision for people needs. Outlooks for windows are into parking lots, much too close to the buildings, and usable outdoor space for tenant needs is too frequently totally lacking.

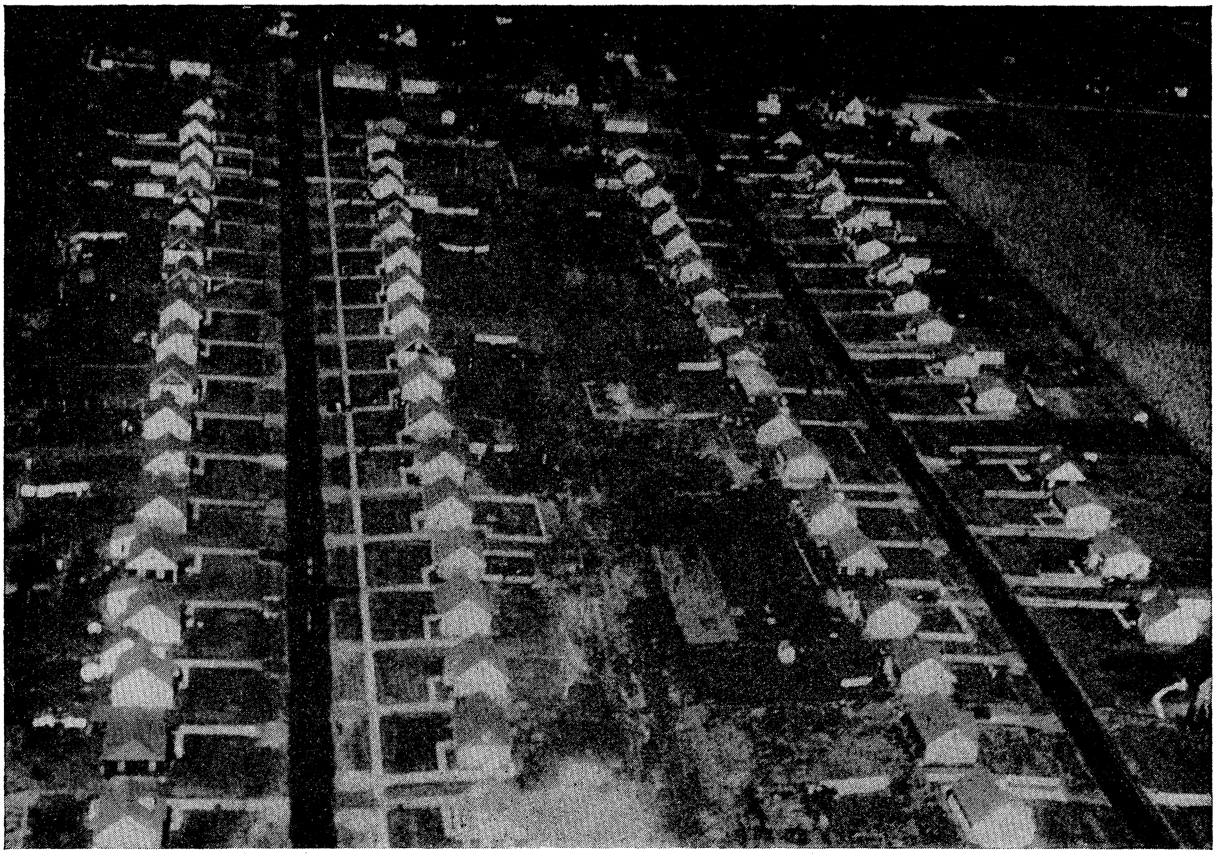

FIGURE 1

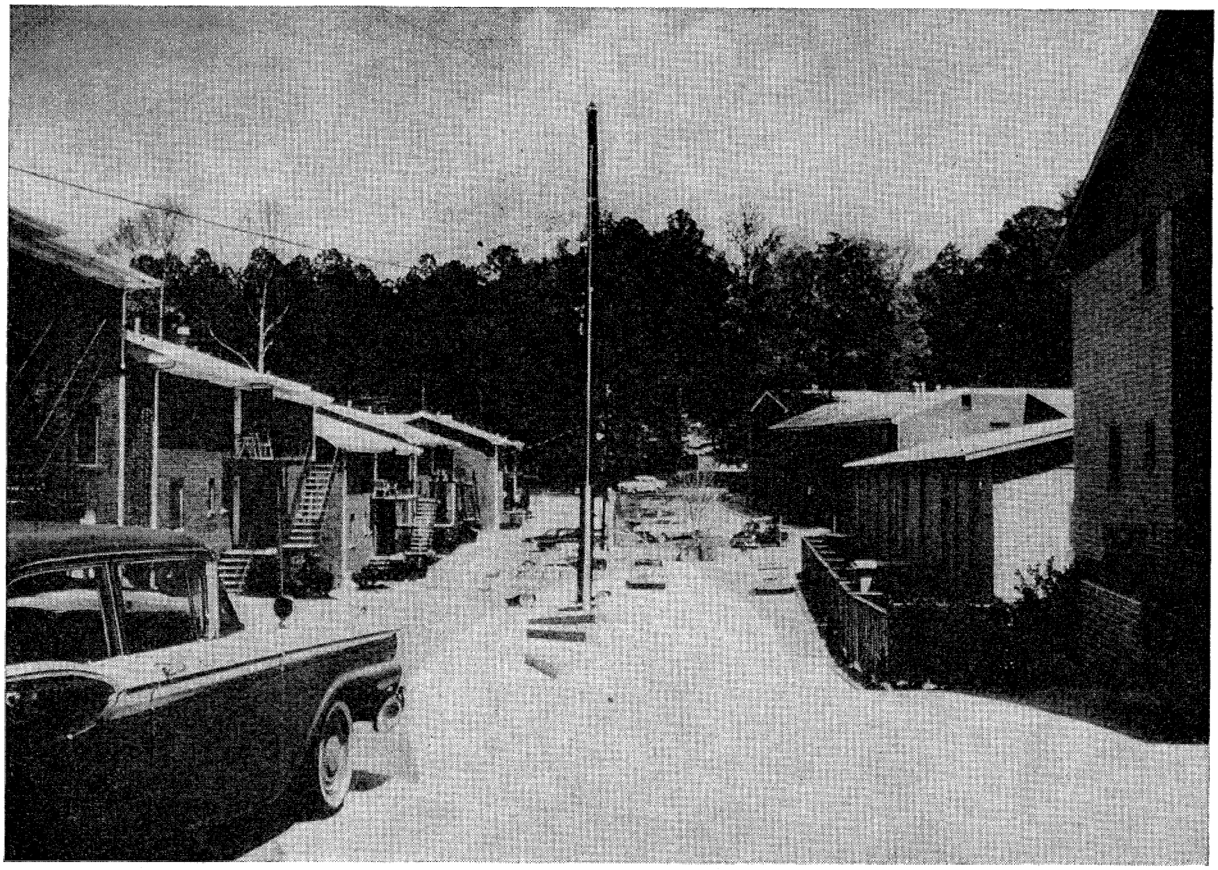

FIGURE 2

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Other projects have the areas that should be private rear yards devoted instead to garbage cans, drying yards, meters, and utility lines. Overbuilding on the site results in crowding the units against slopes, or having to provide parking lots on steep inclines. Notably poor examples of government sponsored housing often are characterized by uninviting high-rise buildings.

(*b*) *Past lack of emphasis on better planning*

Since the inception of the Breakthrough programme two years ago, we have continually emphasized the need for better site planning and greater concern for an improved living environment. The programme is built on the fundamental legislation that requires providing 'every family with a decent home in a suitable living environment'.

Secretary Romeny has recently emphasized the need to combine production with high quality. New project selection criteria require evaluation of the relationship of the proposed project to the physical environment of the neighbourhood. This includes information on, and the intent of the proposer, as to whether the proposed housing will enhance the physical environment of the neighbourhood through such factors as elimination of blight, exceptional architectural treatment, improved land use patterns, minimum or no adverse ecological factors such as noise and air pollution. The backbone of evaluation proposed designs has been the H.U.D./F.H.A. Minimum Property Standards (M.P.S.). These are presently undergoing revisions. The new edition will outline *performance criteria* for land use planning that will require the proposer to address better design and people needs. We in Breakthrough are exhilarated to see this shift as it reflects the requirements we have been advocating.

(*c*) *Lack of systematic approach*

In our Operation Breakthrough effort we have deliberately imposed a process on the site designers. The final site design should be determined on the basis of a *comprehensive examination* of many related influences, site conditions, neighbouring area development, community housing objectives, the housing market and proposed occupant's needs and not by any single influence or blind dependence on traditional solutions. Particularly, we would not be so easily persuaded by the developer's traditional excuse that 'good design costs more'.

Teams of architects, engineers, landscape architects, and planners have supplied a four-phase service to the programme in order to plan and design the nine Operation Breakthrough prototype sites. The four phases, or tasks, are: (1) site investigation and conceptual planning; (2) preliminary design; (3) final design and working drawing development; (4) inspection of site construction.

Our present procedures in the Department do not provide sufficient or adequate guidance to developers for the first task. It is in this area that we are giving major scrutiny in developing the process for evaluation of the early, past-prototype, volume production site proposals. We see the process of task 1 addressing the following major elements or areas of analysis.

(i) *The neighbourhood or site location*

In Breakthrough, we are insisting on an awareness on the part of the developer of a site's specific function and role beyond its property lines, i.e. the impact the development will have on neighbouring communities, schools, parks, shops and transportation as well as a thorough understanding of the specific site needs, uses and space requirements of facilities required for the people who will live there.

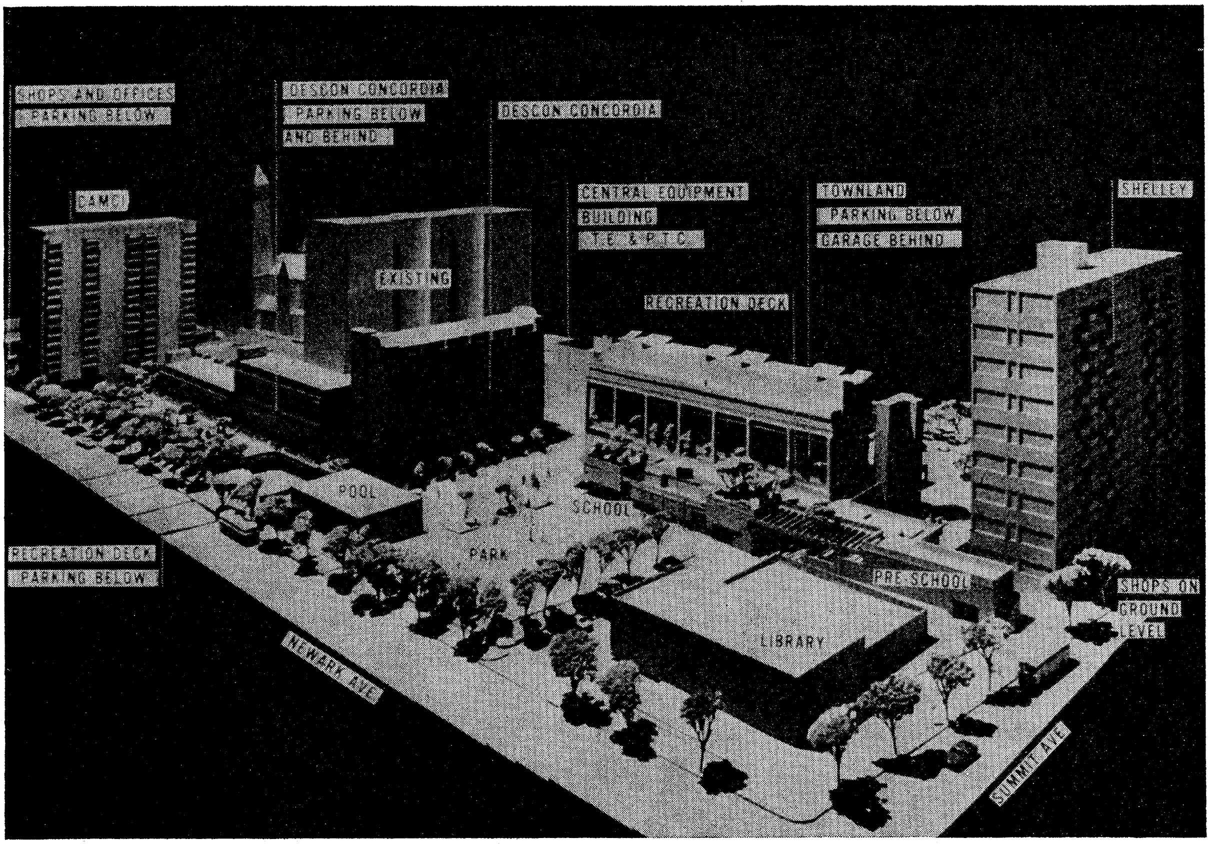

FIGURE 3

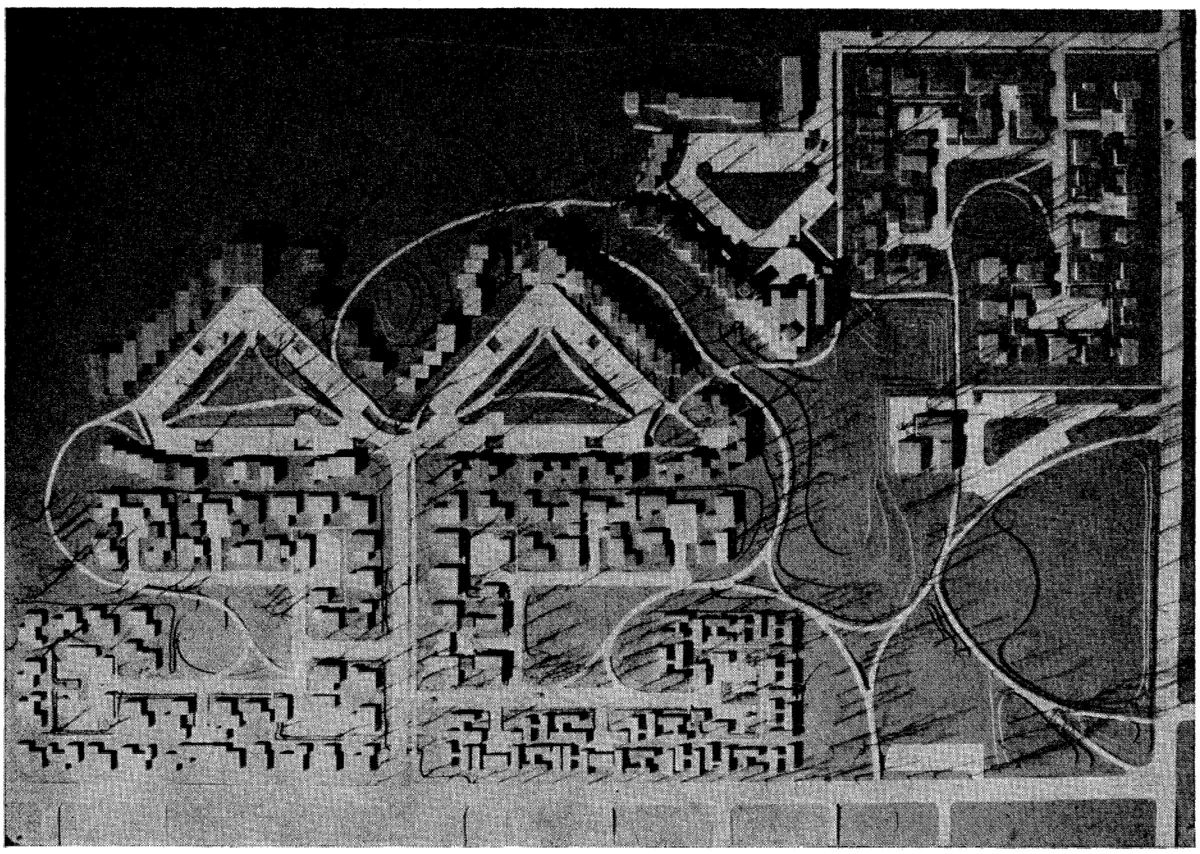

FIGURE 4

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(ii) *The site and its physical features*

Elements to be considered are the topographical constraints, the natural resources such as trees, streams, views, the local climate and wind conditions – particularly the severe conditions, the natural drainage patterns, soil conditions, and other ecological factors, the site easements and size and shape of the tract.

(iii) *The land use programme*

The land use programme must evolve from a thorough appreciation of the future residents' needs. These needs include services such as open space and recreational areas for the range of age groups that might be present on the site, day care centres, laundry facilities, parking spaces required, shopping facilities, etc.

(iv) *The design objectives, based upon the land use programme*

These objectives give verbally the spatial quality and quantity that the designer wishes to propose. Quantification at this step describes optimum interrelationships between the on-site facilities with one another and with the off-site facilities and services.

(v) *Site design*

The site design, or alternatives, should be based upon the analysis, the programme, and the objectives that have preceded this step.

In Breakthrough we have planned for developments that are physically compatible with adjoining neighbourhoods and at the same time attempted to establish a distinctive character and identity for the Breakthrough development.

The initial investigations of the Jersey City, New Jersey (figure 3) prototype site indicated that family housing – an area need – would overcrowd schools. This resulted in on-site planning for community and neighbourhood uses of a 1200 m^2 (13 000 ft^2), 200 pupil kindergarten to fourth-grade school and 650 m^2 (7000 ft^2) for a 90 pupil pre-school facility. These spaces will be leased and the rent will retire the mortgage for this space. Also programmed for this site is 4200 m^2 (45 000 ft^2) of commercial space because the immediate neighbourhood has no convenience shops. The rental income from the commercial space will supplement the limited rental income from low and moderate income tenants which could not reasonably support needed amenities. The commercial area will contain a supermarket, convenience shops and professional office space. An enclosed all-year pool will be constructed on the site. There will also be covered parking, recreation space, decks and general community space.

Figure 4 shows the plan of the Indianapolis, Indiana, site. The neighbourhood park which could be located as a bridge to the Breakthrough community is in the lower right corner. In addition, an attempt is made to respect the scale of the existing neighbourhood. Clustered single-family detached houses are located on the periphery of the site, serving as a transition from the existing grid-iron of detached houses to the higher density and bulkier building massed toward the centre of the Breakthrough site.

(d) *Lack of credible criteria of norms*

We are developing an evaluation technique which will permit differentiation of good schemes from bad schemes. It also will indicate the acceptable quantifiable 'norms' or criteria for various elements in the site design. I am especially pleased that the firm of Lord Llewelyn-Davies is working with us on this problem.

The first phase of this work was to recommend a framework which will allow comparable measurement and evaluation of the physical cost and environmental aspects of the Breakthrough prototype site plans. Four major aspects were identified to be evaluated for each scheme: (1) area and quantity of the elements; (2) cost of the elements; (3) accessibility of the elements; (4) environmental quality.

Phase two will develop the computer and manual technique, based on the framework, which will be a procedure, with criteria, for evaluating proposed site designs. This development will take the form of a computer-based mathematical model and a simplified technique for field application.

Our intent is to describe, or quantify, the optimum functional aspects of a scheme. An open question is whether or not guidance can be provided for the non-quantifiable areas, such as aesthetics, or the form and shape of exterior spaces beyond the minimum dictated by the intended use.

In your country, some basic study has been done using a computer program for evaluating housing layouts in statistical terms, while attempting to balance the variables in the design programme with each other, and sort alternative layouts to select optimum solutions that represent a 'best-buy'. Our model would permit 'trade-offs' in the land use programme to be evaluated in terms of dollar cost. It may be possible to extend the analysis in terms of capital cost and maintenance 'trade-offs' and social cost-benefits.

(e) *Site development inefficiencies*

Typically 25 to 35% of the land area in our suburban developments is used for vehicular circulation. Added to the area covered by dwelling units, plus required front, side and rear yards, little or no common open space remains. In our Indianapolis site, only 17 to 20% is devoted to paved vehicular areas.

It must not be overlooked that there are institutional constraints to innovation in some areas of site design and engineering. At our King County site in the State of Washington, we have a circular drive and it was our wish to use a curved sewer to avoid numerous man holes and minimize cost. These curvilinear sewers have been used in other communities, but in this instance the County would not accept this configuration. Rather than not having the County dedicate this sewer line and have the maintenance as a cost borne solely by this development, we installed a conventional sewer.

Another factor influencing the way land is used in developments is the housing type chosen. Developing every parcel of land to maximum allowable densities can result in monotonous physical appearance, increased site improvement costs for the total site since the majority of the site area must be disturbed, and little or no variation in housing type since it is quicker and cheaper to build repetitiously. The lack of variety and inefficient use of open space in most developments has resulted in neglect of varying needs of different size families.

The basic question with which we are faced is, now that we know all the things we *should* be doing, to what system do we turn to actually advance the cause of site planning? In Operation Breakthrough, we have selected the housing cluster approach.

This approach separates vehicular and pedestrian circulation, aggregates open space for communal use, provides greenways linking the open spaces and the housing units, concentrates required parking at specific locations in the development, and is more responsive to the ecology and natural features of a site. Cluster planning is sometimes identified as a p.u.d., or planned unit development.

The variety of housing types permitted under some p.u.d. ordinances will permit a variety of family sizes and income levels. P.u.d. represents a great potential for an economic and social mix as well as a safe and viable living environment. The principles of cluster planning were established in the Radburn plan in 1927. We have rediscovered it in the 1960s and hope that Breakthrough will *prove* its acceptability for the 1970s.

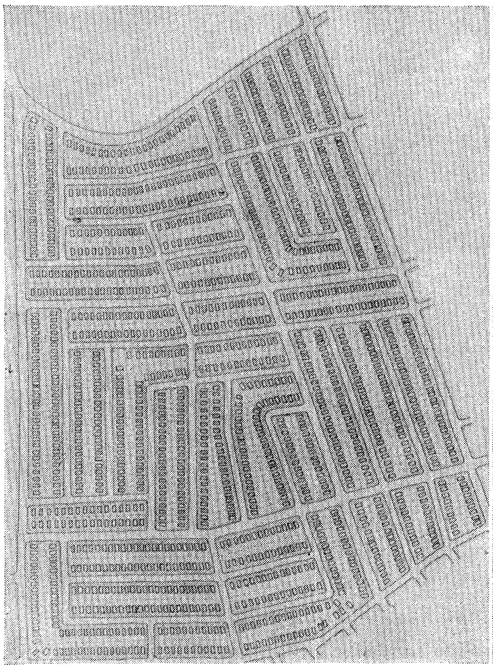

FIGURE 5

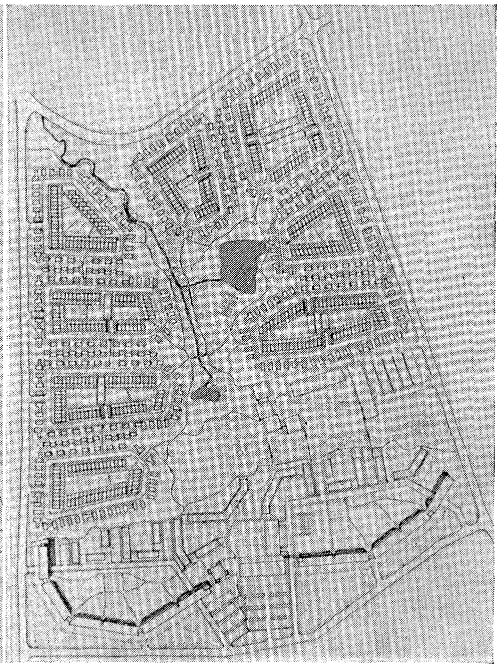

FIGURE 6

A study completed in 1968 by the New York City Planning Commission on a planned unit development amendment to the zoning ordinance showed the following analysis. A typical semi-detached house development on 8 hectares (20 acres) would have 2.5 hectares (6.3 acres) in streets (31.4 %), no common open spaces, 198 units with allowable floor area per unit of 130 m^2 (1400 ft^2) with 7.5 rooms per unit. The proposed p.u.d. ordinance would allow town houses or attached units totalling 213 units 1.66 hectares (4.1 acres) in streets (20.5 %), and 3.5 hectares (8.6 acres) in common open space. The allowable floor area would be 176 m^2 (1900 ft^2) with 9.8 rooms per unit. Figure 5 shows a specific parcel of land as it is frequently developed. Figure 6 illustrates the same land parcel as it could be developed, without loss of units and with, what I am sure you will agree, are major improvements.

In Memphis, Tennessee, for instance, we are building a high rise for the elderly, a high rise and garden apartments for students from the adjacent university, and garden apartments and townhouses for low and moderate income families. In Sacramento, California, housing for the elderly is provided together with single family detached and attached units and garden apartments for a mix of families of varied sizes and incomes.

(*f*) *Ecological and environmental considerations*

In our programme, we have addressed ecological factors and environmental conditions. We firmly believe that we are building better communities because of this.

Many of the insensitive and inefficient traditional approaches to site planning, prevalent across the United States today, were identified and new solutions were designed for implementation on the Breakthrough sites. Various sites have approached these problems in a variety of ways. Understanding the sites' ecology and recognition of the positive potentials of their natural resources resulted in the following. On the Kalamazoo, Michigan, site, one of our concerns was the possible pollution effects on nearby Spring Valley Lake by contaminants and hydrocarbons from drainage run-off. To prevent this, a storm-water drainage system was designed to include leaching catch basins. Periodically the undesirable residual elements are cleaned out of the catch basins.

At the Memphis site, an early analysis of the neighbourhood and site environment established the high vehicular noise from bordering boulevards. Certain portions of the site were found to exceed H.U.D.'s new standards of acceptable noise levels for housing sites. Rather than eliminate the site, we accepted this noise impact as a design constraint and challenge. As a result, the site planners designed an earth bank of sufficient height to serve as a noise shield along a portion of the site boundary. We anticipate that a noticeable and most pleasing reduction in noise level will result once one enters the site.

(*g*) *Constraints of existing regulations and controls*

A certain amount of negative influence on the design of residential sites has been effected by zoning ordinances, subdivision regulations, and even our F.H.A. minimum property standards where the minimums set have been taken as maximums by developers. This is not the intent of such regulations. It is increasingly evident that zoning codes and subdivision regulations can and often do inhibit quality site planning, and, in fact, may prevent it.

The p.u.d. ordinance allows a new housing development to meet the objectives of zoning and subdivision regulations, such as the control of overall densities, as well as architectural attractiveness, and preservation of neighbourhood character, without the restrictions on minimum front, side, and rear yards, which limit site design flexibility. It encourages more effective land use by allowing a wider range of planning solutions to the problems presented by the physical and environmental features of the site. Planned unit development permits a planner to give first priority to addressing the human needs of the residents.

Among the other innovations that will affect site and building design are the use of a pneumatic solid waste collection system and total energy systems. I will discuss these in more detail later, but mention them here since they eliminate the prevalent and ugly use of garbage cans and will improve a number of environmental factors.

As a major issue in site planning, I believe I should emphasize consideration for car parking. One of our *major* site design problems – parking of private cars – has been approached in a variety of ways. In Memphis, three-fourths of the on-site parking has been covered by a pedestrian mall. The mall or deck will be used for open space recreational purposes as well as for small, light-weight pavilion type structures. There will be direct pedestrian bridge connexions from the deck of the garden apartments and high rise structures surrounding it. In flying over cities of America, you will see that many of the central cities abound with open parking lots. Here we have covered that use and recaptured the area for a community amenity and, we believe, have pleasantly integrated the parking area into the site.

At Jersey City, we have put the parking into a combination of parking garage and single level parking, distributed under other site uses, covered by elevated plazas or open on rear portions of the site. The majority is screened from view. The approach on the Seattle inner city urban renewal site is similar. On the St Louis site, the planner has allocated the parking into modest sized lots distributed on the periphery of the site. By keeping the lot sizes modest and applying landscaping treatment, the necessary parking should have minimal environmental impact.

On the other sites, some of which have suburban characteristics, parking is conveniently located in lots near or within housing clusters. At King County and Macon, because of the constraint of hilly terrain and many trees, the houses are clustered around the parking areas with outlooks from the housing into the undisturbed wooden areas of the site.

(*h*) *Conclusions*

Throughout all of the prototype sites, the planners have tried to consider needs of the variety of people that will live in the Breakthrough community. The toddlers are accommodated, the subteen, teenagers, and adults are provided opportunities that might accommodate their needs. There are community buildings for group and community needs or functions, swimming pools, and where facilities are not provided on site, but in the adjacent community, provision is made for easy access from site to facility.

What we have created within our prototype sites is the potential for viable, cohesive, interesting communities built on a physical fabric that recognized the needs, we believe, of the future residents. Also, we have consciously recognized the necessary interfaces and linkages with the surrounding neighbourhood and services. We believe the Breakthrough programme will serve as a real catalyst to move the housing industry, and all related functions from government to developers, to banks, to a greater appreciation of the essentiality of good, professional site planning.

At Sacramento, the cluster plan is not amorphous but carefully structured on a modified gridiron framework. It suggests that older portions of the city could be restructured in a similar pattern, using many of the existing streets and utilities. The plan is composed of a number of small clusters where neighbours share a small common playlot. These in turn are clustered around a central common which will provide the facilities for subteens, teenagers, and adults. All facilities and open spaces are interconnected and give a focus and structure to the community.

At Indianapolis, a major feature of the plan is the providing of single family detached houses on 325 to 370 m^2 (3500 to 4000 ft^2) lots (compared to 465 to 650 m^2 (5000 to 7000 ft^2) lots in typical tracts). Each lot has a private yard and each cluster a semi-private community open space. The overall density of yield from the land is the same as the typical tract, but the use of the land provides not only the necessary private yard space but abandons the useless front and sideyards and aggregates it into a 0.4 to 0.8 hectare (1 to 2 acre) parklet within each cluster.

It should be noted that the variety of sites selected and the diversity of architects and planners

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used in the design of these sites have resulted in solutions that may be applicable in part or in whole to other sites or projects, or there may be embodied in these designs the nucleus of solutions for suitable residential living environments.

2. Operation Breakthrough performance guide criteria†

In preparing to evaluate the suitability of Breakthrough housing systems, it became apparent that certain of the systems could not be judged by normal prescriptive building codes because these systems differed substantially from conventional building methods which served as a basis for these codes. Further, we found that certain safety, durability, and livability issues in housing were not specifically addressed in most codes.

It was determined that *performance* measures were needed to encourage innovation and to evaluate new housing systems. In a remarkably short time, the National Bureau of Standards developed such an interim set of performance guide criteria. A highly qualified committee of the National Academies of Sciences and Engineering reviewed the guide criteria. The resulting criteria are serving as the basis for evaluating Breakthrough housing. These guide criteria are continuing to be evaluated and adjusted based on comments from various elements of the housing business and on results of Breakthrough testing. Some elements of these criteria are discussed below.

(*a*) *Structures*

Two aspects of structural performance are considered in the guide criteria: (1) is the structure safe? and (2) does the structure perform well in service?

Structural safety is generally related to the structural attribute of adequate strength. Structural performance in-service is related to the attributes of adequate stiffness and rigidity and adequate resistance to local damage that may be caused under service condition. Conventional structures, with which we have had extensive experience, generally possess these attributes; competition in the industry and user rejection over the years have eliminated most undesirable attributes. However, this process is too slow in times of rapidly developing technology and changing needs and tastes. Further, the public could not afford the consequences of the introduction of unsafe or otherwise unsatisfactory systems in great quantity. But neither can it afford to stall innovation by rejecting untried ideas. With innovative, untried systems it is, therefore, necessary to introduce *performance* requirements which include areas not normally considered in the building codes.

One of the major problems we face is the lack of sufficient knowledge about the true quality of present methods. It became necessary to test traditional construction elements of the Breakthrough systems to determine whether levels required by the criteria were actually greater than those now in acceptance for conventional systems. For example, we tested a traditional house for drift by subjecting it to horizontal loads and found that its performance level exceeded the criteria requirements.

Figure 7 shows a typical example of an advanced structural system – the TRW system. Here is a test on a wall specimen containing a paper honeycomb core, a reinforced glass fibre skin, with an outer layer of gypsum boards. It is obvious that performance testing was necessary to determine the strength and stiffness of this new system. Some specimens were tested in a normal

† I would like to acknowledge the assistance of staff of the National Bureau of Standards in preparing this section.

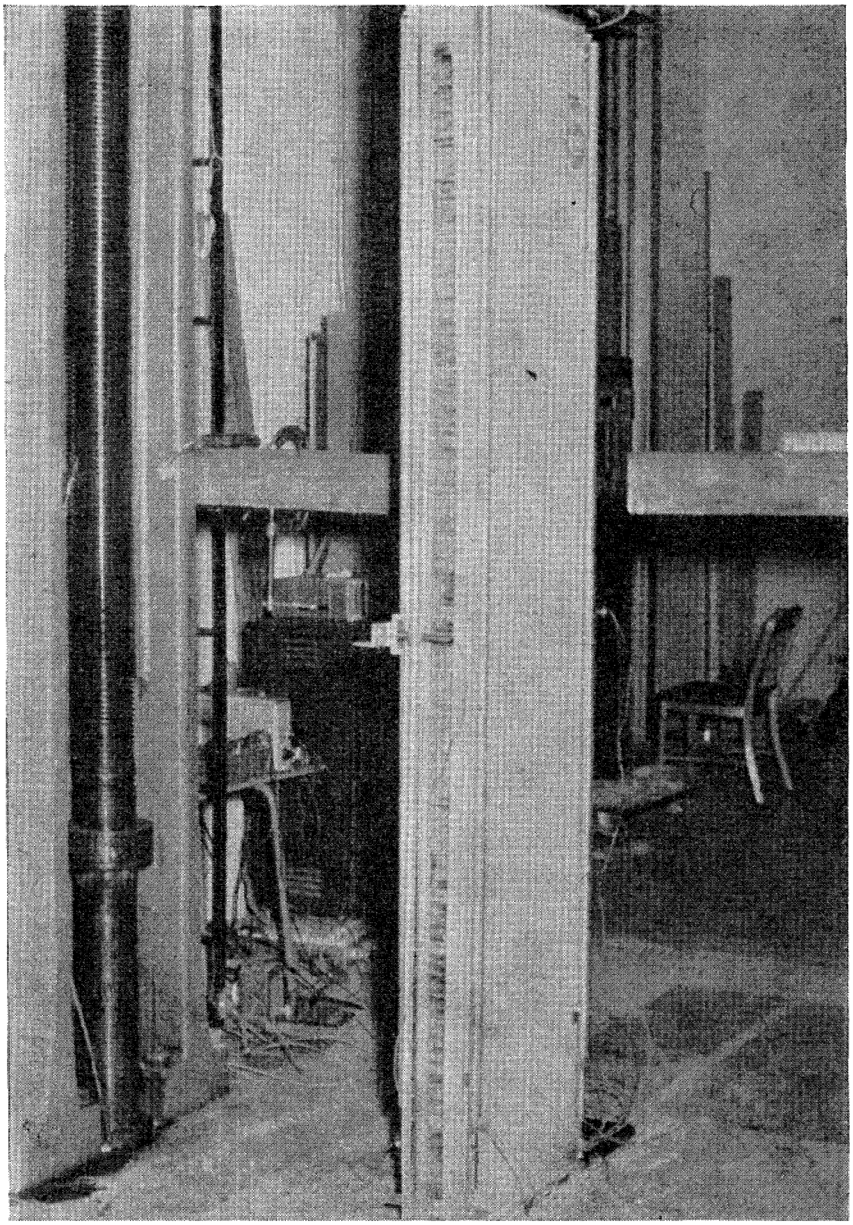

FIGURE 7

dry state. Others were conditioned by wetting and steaming and then tested. In this case, failure loads for dry specimens ranged from 12000 to 18000 lbf (54 to 80 kN) and of wet specimens from 7000 to 9400 lbf (31 to 42 kN). Thus, conditioning reduced the load by about 50 %. The required ultimate load capacity was 4000 lbf (18 kN) and the strength was deemed satisfactory.

Another difference between the criteria and present codes is the inability of codes to measure the safety margins of innovative systems. Traditionally, safety margins take into account strength variability and deterioration with age. For untried systems, such parameters must be estimated and evaluated. One example is the problem of evaluating the strength of structural adhesives. Many codes require mechanical fastening in addition to adhesives because durability of adhesives is not known.

Evaluation included determination of time-fracture characteristics of materials by testing specimens to destruction under loads applied for various lengths of time and under various temperatures and moisture conditions, including extreme conditions expected. The same had to be done for the various adhesives and finally for structural subassemblies. As a result of these tests, the original design had to be changed by connecting several modules not previously connected in order to provide added racking resistance.

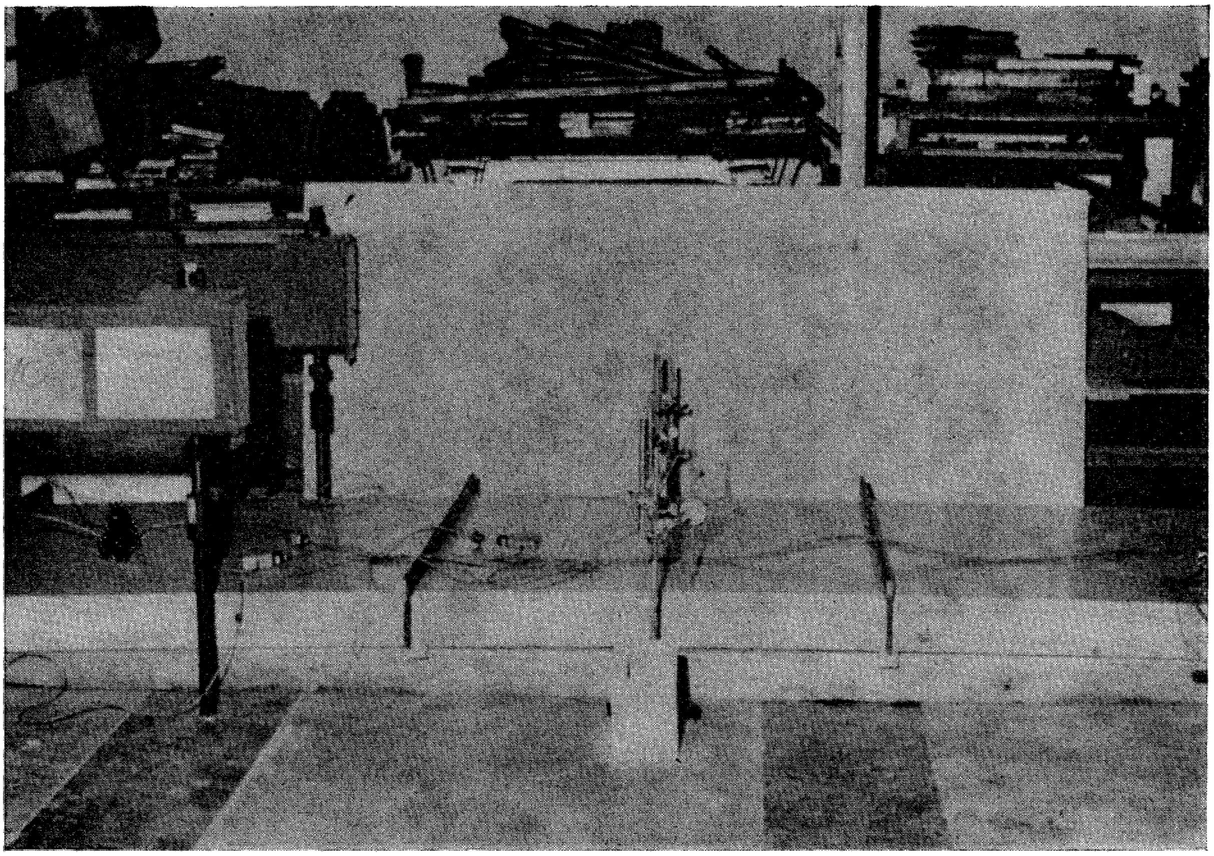

Figure 8

Another innovative system that had to be evaluated by testing is Republic Steel. This single-story system uses structural panels having a steel skin and paper honeycomb cores. Our confidence in analytical evaluation methods is not great enough to rely exclusively on calculation. Figure 8 shows a test on one of their roof panels. To simulate the most severe environmental condition, this panel was submerged in water for several days.

In this case, performance testing played an important role in system development. The first test sample subjected to environmental conditioning showed serious deterioration in the bond between the skin and the core. Further study indicated that the adjesive used lost much of its strength in wet conditioning. As a result of the test, another adhesive is now used which performs well. The test also detected potential panel weakness caused by the splicing of core material. This led to recommendations for elimination or improvement of splicing. The testing in these previous examples not only evaluated proposed systems; the information gained substantially contributed to the improvement of that system.

Another system that was improved as a result of performance testing is the Shelley System. This system consists of 4 m (13 ft) wide and 16 m (53 ft) long concrete boxes weighing 46 tons each. These boxes are stacked in checkerboard pattern as shown in figure 9.

The boxes, while reinforced, derive their structural strength from four ribs, each of which consists of two columns with a beam at the ceiling level. Since grouting was to be avoided, 6 mm ($\frac{1}{4}$ in) neoprene bearing pads were planned for the column connexion from box-to-box.

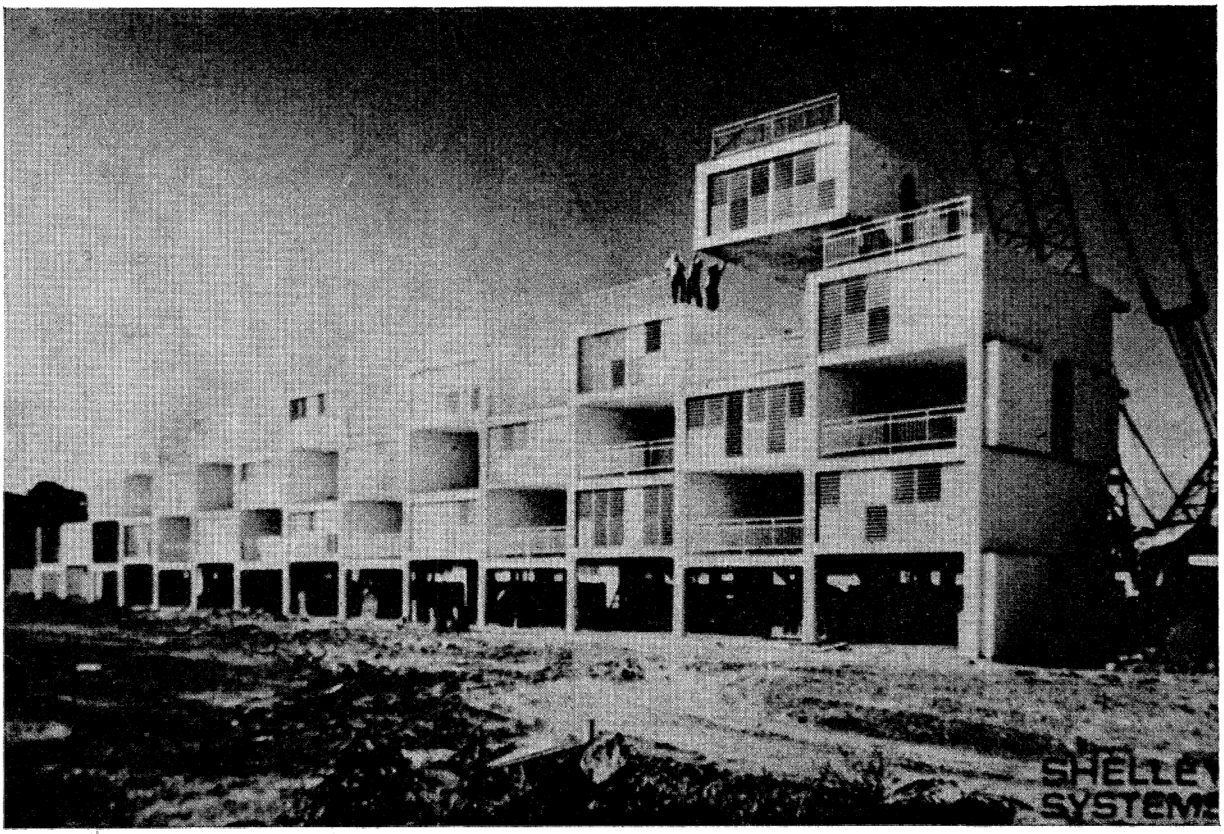

FIGURE 9

These pads also fulfill the function of equalizing bearing pressures and 'picking up the slack' from construction tolerances. Since reinforcement is not carried through this joint, except for a single steel dowel in the centre of the column, the entire load is transmitted through plain concrete bearing.

Stresses on plain concrete permitted by present codes would result in oversizing the column. Confining reinforcement was, therefore, provided to increase the bearing capacity of the concrete. The bearing strength of the concrete, in an improved joint consisting of a neoprene pad between two steel plates, was greatly increased and indeed the state-of-the-art in jointing techniques for precast concrete was advanced.

Examples of other structural performance tests include impact tests on walls and on floors and concentrated load tests for floors. All these tests simulate user activity. As systems become more innovative, more and more tests will have to be performed on full-scale three-dimensional modules and the test methods will have to be standardized.

Finally, something should be said about the evaluation process itself – evaluation as a creative process, as conducted in Breakthrough.

The Housing Systems Producers in Operation Breakthrough have been free to seek innovative solutions to housing production subject only to requirements for performance given in the Breakthrough criteria. It is, of course, essential that their plans and specifications be evaluated to achieve a high degree of assurance of the required performance. This activity is far different from the traditional code-checking of a building code department. The traditional prescriptive code says, for instance, that wall studs must be wood 5 cm × 10 cm (2 in × 4 in) on 41 cm (16 in) centres, and the checker looks at the working drawings to see that they are. The performance specification says walls must not be damaged by occupancy loads. The Breakthrough criteria assist the designer and evaluator with some quantitative expressions for occupancy loads and damage, but still it is necessary to conceive potential mechanisms of damage, formulate the resistance to each mechanism and identify the critical loading configuration.

(*b*) *Materials and durability*

Simply stated, durability is the time-dimension of performance and, hence, is related to the ageing process. Ageing has a major influence on performance. The rate of ageing is determined by the nature of the material in question, its compatibility with the adjoining materials and by such factors as exposure, climate, use and maintenance. The nature, intensity and frequency of the ageing factors acting alone or with others, often synergistically, produce changes which alter the performance characteristics of the material. The ability of a material, assembly or structure to resist or, more often, adjust to the ambient forces for a normal period of time with normal usage becomes a necessary measure of performance. The cost/benefit ratio of durability and performance should be a prime consideration not only in the selection but also in the evaluation of materials which meet the performance criteria.

The preparation of the guide criteria clearly demonstrated that there are some developing technologies for which there is simply not enough knowledge for a full evaluation on a performance basis. We are currently working with the National Bureau of Standards on several long-range projects in an attempt to fill these knowledge gaps. For example, as indicated earlier, the rapidly expanding use of adhesives in buildings has outstripped the evaluation and testing knowledge. The major problem facing the adhesives industry is that of measuring and predicting the durability by laboratory tests. Although laboratory tests for various adhesive properties are specified in A.S.T.M. or Federal Test Methods, no existing test or series of tests provide information which adequately relates to durability and, hence, performance over the expected lifetime of the building.

Another object of long-range research is plastics. The use of plastics on the structure's exterior in roofing, cladding, paints, coatings, sealants and caulk and waterproofing systems has become common practice. Yet, at the current state-of-the-art of plastics technology, it is extremely difficult to predict with accuracy the long-term performance on the basis of short-term tests.

If three parameters are known about various materials used in a building system, their behaviour can be predicted with some degree of accuracy in any combination of use. This approach results in a tremendous simplification in the measurement of performance. The three parameters which should be determined are (1) the chemical and physical properties, (2) the changes which occur in these properties when exposed to the intended environment, and (3) the compatibility of materials with other materials which make up the building system in question. While it is relatively easy to determine the pertinent properties of a material and the interaction between or among materials, it is much more difficult to determine the effects of time and exposure on those properties. We are working to develop criteria which consider all three parameters.

(c) *Fire safety*

(i) *Test method inadequacies*

The commonly accepted procedure for evaluating the fire endurance of elements in a building is the A.S.T.M. E 119 method, 'Fire test of building construction and materials', a test adopted about 1908 and modified little since. As long as the materials and constructions being evaluated remained comparable to the ones for which it was developed, the test method remained valid. With the use of new materials and constructions such as those submitted in the Breakthrough programme, we have found deficiencies in the test. For example, there is no provision for a standard to test a load-bearing wall which has a fire exposure from both sides simultaneously.

We were faced with the problem that, in modular construction, load-bearing walls may be subject to fire from both sides, yet no test furnaces were available to evaluate the performance capability of the systems in question. The National Bureau of Standards developed an analytical heat transfer programme by means of an iterative solution to evaluate the bearing walls with fire on both sides. Additionally, we believe we will have to develop a new set of criteria for the fire performance of double party walls found in modular construction and not covered by the present codes.

There are other deficiencies in the E 119 test method which have come to light and which must be resolved. For example, the pressure in the test furnace is not defined. Whether the furnace is operated under a positive or negative internal pressure makes a large difference in the amount of gases and fumes coming through the construction. The pressure also affects the degree to which fire penetrates the test construction.

Also, the standard E 119 fire test makes no provision for measuring the amount of smoke and toxic gases generated by the construction. In testing some walls made of fibreglass-reinforced polyester, we found an intolerable amount of gases and smoke generated by the construction, even though they passed the E 119 stipulated requirements. Yet another major deficiency is the lack of a defined method of evaluating construction with small fires. This becomes especially significant as we become more innovative in the use of chemical and plastic construction materials.

(ii) *Smoke detectors*

Studies have been conducted of fire deaths in residences in the Province of Ontario, Canada. The results indicated that 59 % of the persons asleep at the time of the fire could have been saved by an adequate smoke detection system. Studies by the National Fire Protection Association on residential fires in the United States have indicated that 52 % of the fatalities in these fires were caused by smoke inhalation and only 44 % by burns. With these data in hand, it was relatively easy to decide that we should provide smoke detection for safety in residential construction, even though detectors are not required in *any* of the model codes. Specific criteria for residential detectors were not available. We, therefore, initiated a study of the mechanics of detectors and the state-of-the-art to develop a set of criteria which would provide for an inexpensive residential detector. The criteria placed emphasis both on reliability and extended service life.

(iii) *Life safety system*

The Breakthrough criteria attempted to provide a system for life safety in fires, particularly in high-rise buildings, which would be equal to or better than those now in use. As a result, several new concepts were introduced, in the form of new requirements which do not exist in the current codes. The system consists of the following components: detection, alarm, design of passageways and exits and control of materials.

An early warning system of either the smoke or product-of-combustion type is required. Detectors spaced on 9 m (30 ft) centres are required in corridors. Since the corridors would be passable for a longer period of time, increases in travel distance were allowed above those normally permitted by the code.

Once a fire is detected, there must be an alarm. Most buildings have alarm systems which ring throughout the building, but experience has shown these systems are not effective. When the alarm rings, no one feels an immediate presence of danger. Therefore, we went to a zoned system in which the alarm sounds on only the floor of the fire, the floor below and the floor above. When an inhabitant of the building hears the alarm of this system, he knows that danger is near.

Unfortunately, in our state of knowledge, there is no good indication as to whether the alarm system should be visual or audible or both. Although bells were required in the criteria, there is a growing body of opinion in the United States which holds that voice type of system, with possibly flashing lights for directions in the corridors, would be used for greater effectiveness. This question should be investigated.

Many deaths due to fires have been the result of people fleeing their burning apartment and leaving the door open, allowing the fire to get into the corridor. In the case of a nursing home fire in Marietta, Ohio, about 30 people died because of the lack of self-closing doors. For this reason, all doors opening onto the corridor are required to be self-closing.

In addition, it was felt desirable to control smoke at its source by controlling the materials on the building surfaces. Therefore, criteria were added which place control on the smoke propagation properties of interior finish materials. These criteria are also not found in current codes.

(*d*) *Acoustics*

Major property management firms report that noise transmission is one of the most serious problems facing managers of apartment buildings throughout the country. Managers and owners of apartments readily admit that market resistance is not only increasing as a result of excessive noise transmission but also that lack of both acoustical privacy and noise control are the greatest drawbacks to apartment living.

The basic noise problems are due primarily to light-weight building structures, poor acoustic design – including site selection and arrangement of functional living spaces without regard to noise sources, poor workmanship which nullifies planned sound insulation, an increased use of mechanical appliances, and the greater concentration of people in smaller areas such as in high-rise apartments.

These are the problems that the Breakthrough acoustic criteria are intended to alleviate. By citing light-weight building structures, increased mechanization, and the prevalence of high-rise construction as causes of the noise problem, there is no intent to deprecate these trends in architecture and construction. Rather, the intent is to point out that modern buildings require more specific attention to noise control than did the massive constructions of the past.

Without minimum standards, the consumer must purchase a dwelling unit on the basis of glorified phrases of praise by the salesman. It is not until after occupancy that the consumer knows whether his home is liveable. He will know *every day* whether his need for privacy or quiet is fulfilled. Every day he knows that there is little he can do to improve certain deficiencies without a great deal of expense – some of which could have been corrected at a minimal cost during construction. One thing we learned in Breakthrough was that builders, or systems producers, are generally unaware of potentially inexpensive methods of acoustical improvements. Therefore, they think such improvements must be prohibitively expensive so the changes are avoided. Part of the confusion stems from a lack of clearly defined acoustical goals.

Goals of acoustic criteria

The guide criteria developed for the design and evaluation of the acoustic environment of prototype housing in Breakthrough are intended to permit attainment of three distinct, but related goals: provision of a sufficiently quiet environment in which to live comfortably; provision of acoustical privacy between dwelling units; provision of acoustical privacy within a dwelling unit.

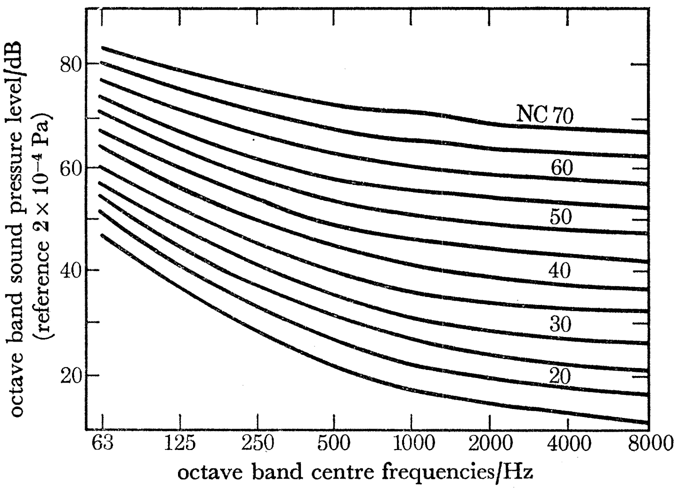

FIGURE 10. Indoor noise criterion (n.c.) curves.

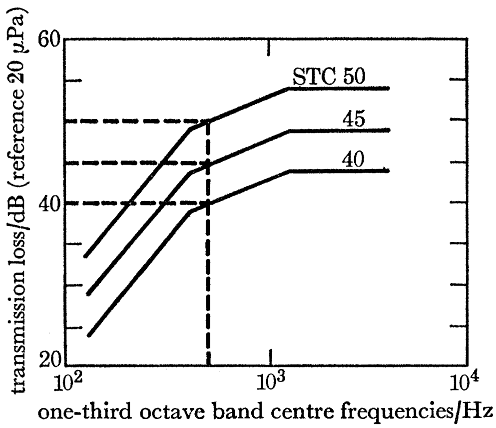

FIGURE 11

Criteria which are suitable to all situations and environments would be virtually impossible to establish and very difficult to apply. Therefore, the intent was to establish criteria which would satisfy a majority of the occupants most of the time and yet would be easy to administer.

One significant problem is that these goals can be in conflict with one another. For example, while it may be possible to design out the major source of outside noise, and, therefore, effectively meet the first goal, the newly attained quiet may well bring a new intensity to the lack of privacy inside the structure. Inter-apartment noises that were previously dulled by the conflicting outside noise now are clearly heard and the occupants' antagonism and aggressions are directed at their fellow residents.

A most difficult problem is the provision of measures of the acoustic criterion. We are using the NC curves devised by L. L. Beranek which provide a single-figure rating for interior noise levels. The following graphs show the curves as they plot speech interference and annoyance (figure 10). We are also using the 'Sound Transmission Class Normalized Isolation Class' rating systems to better measure the difference in average sound pressure levels in rooms on opposite sides of a test partition (figure 11). In order to assess the impact sound insulating properties of floor–ceiling constructions, we are using an adaptation of the International Standard Organization method established by the American Society for Testing Materials.

I want to emphasize that the important thing is not the specific graphs or the many rating systems that are available, but rather the lack of available research of standards concerning the real needs and desires of those who occupy our dwellings. For example, what is the degree of privacy desired by parents? Do they really want to be able to hear everything in order to feel their children are safe, or is there a higher level of priority attached to reduction of bathroom and bedroom noises? Can both goals be achieved? At what cost?

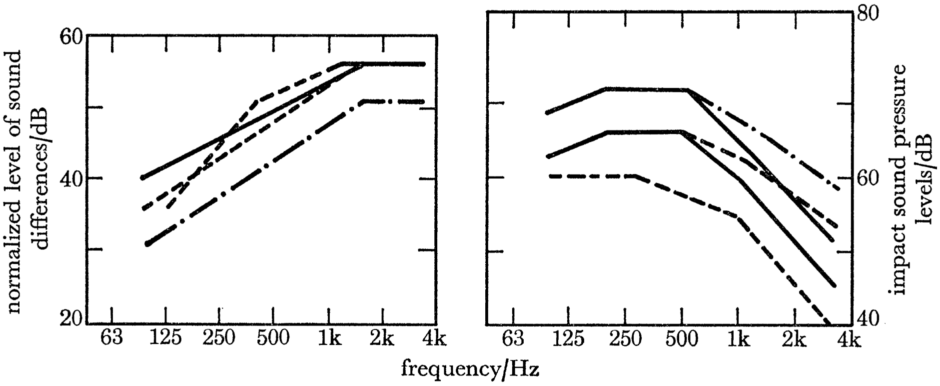

FIGURE 12. English criteria: – – –, grade I flats; –·–, grade II flats; —, house standard (house party wall grade).

FIGURE 13. English criteria – – –, grade I; –·–, grade II; —, with linoleum.

The last two graphs compare the Breakthrough criteria for inter-dwelling acoustics with your British criteria and show how closely matched the contours really are. Figure 12 shows a striving for the highest normalized level of sound difference, while figure 13 shows a striving for the lowest impact sound pressure level.

It may be helpful to point out that our criteria go beyond those now required by the normal H.U.D./F.H.A. Minimum Property Standards (M.P.S.). There no requirements are given for partitions within a dwelling unit and none are given to ensure a quiet environment. In Operation Breakthrough both requirements are stated. While the F.H.A. Minimum Property Standards base compliance on laboratory tests, the Operation Breakthrough criteria are based on performance (field tests). Laboratory tests are used as a guide to determine in the design stage whether compliance could be met.

The use of industrialized, especially modular, housing has its good and bad points, acoustically speaking.

One advantage is that the combined wall or floor/ceiling construction that results usually has a minimum of coupling between the two interior surfaces and thus provides the potential for a superior partition. One drawback of modular housing can be illustrated in the case where a module for a garden apartment includes a party-wall in the centre of the module. This party-wall might separate two living rooms, kitchens or whatever. Because of the need to transport modules, the structural integrity of the module must be maintained.

Even though a wall can be constructed which in itself provides a high degree of sound isolation, one major coupling path exists – the continuous floor under the party-wall. Additionally, a flanking path sometimes exists in the void space between the first- and second-floor modules since the wooden floor does not attenuate sounds very well. These problems can be corrected by making a saw cut in the floor in the party-wall cavity and providing a firestop as shown in figure 14. A better location for the insulation is also shown.

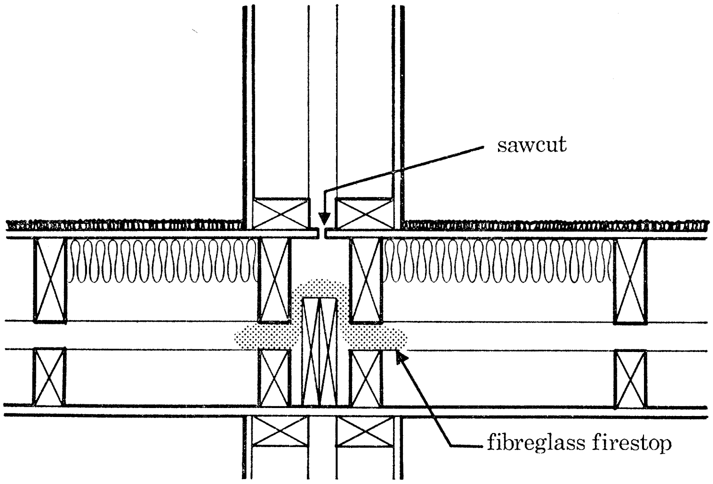

FIGURE 14

Specific examples of the problems and progress of the Breakthrough systems can be illustrated by T.R.W. and Material Systems, both of which use new, light-weight fibreglass reinforced plastic materials. Material Systems Corporation has partitions of chopped glass fibre reinforced polyester. Although this material is very light-weight and innovative from a building standpoint, the sound transmission loss of such partitions is very poor. A more massive material such as gypsum drywall must be added, especially to party-walls, to provide the proper sound attenuation. T.R.W., which has a fibreglass modular shell, has had to go to gypsum drywall laminated to their basic shell to satisfy both the sound attenuation levels and fire safety criteria.

The Townland System has a supported land system where modules are placed on different levels of a multilevel frame which creates artificial land space. The vertical acoustical privacy is greatly enhanced by this separation of dwelling units.

A survey in New York City a few years ago indicated that occupants of apartments would be willing to pay an additional $15 a month for better acoustical quality – a pretty strong statement coming from a city where prices are already very high.

Frankly, and despite consumer desires, the response of the housing system producer to the acoustical criteria of Operation Breakthrough has been mixed. The majority of the housing systems producers have been unwilling to spend even a minimal amount to increase the acoustical quality of the dwelling unit unless it is absolutely required in order to complete the Operation Breakthrough programme. Much resistance has been met to incorporating even those items which can be done very inexpensively, e.g. vibration isolation of the garbage disposer from the sink, the dishwasher from the floor and plumbing, resilient pipe hangers, water-hammer arresters, and design of duct work to minimize noise transmission. Many such simple modifications may cost only $2 or $3 yet can be responsible for approximately a 10 dB reduction in noise level.

The objective of H.U.D., quite understandably, is to see that every housing system producer is able to provide a product in a reasonable time and at a reasonable cost. It is our responsibility, perhaps our greatest challenge, to see that these production goals are achieved with high-quality construction.

In Operation Breakthrough, it is doubtful that any housing system will meet all the criteria for acoustics. This does not imply that no progress has been made concerning acoustics in the building industry. More builders than ever before are now at least aware that acoustic quality in buildings is becoming an essential consumer requirement. A great deal of information can be drawn from the testing of Operation Breakthrough housing. At any rate, a number of the Operation Breakthrough housing systems should afford better acoustical privacy and better control over the noise than most of the homes built in the United States today.

3. Environmental systems

The Breakthrough programme has a real potential for significant advances in environmental quality in housing, if that quality is recognized as a legitimate responsibility on the part of the designer and builder. One of the most notable achievements of H.U.D.-sponsored housing research has been the creation of the means by which building service system innovations can be evaluated and introduced into practice. The following sections portray specific examples of the accomplishments, lessons, benefits and implications that have arisen from H.U.D.-stimulated or supported research in the building transport system areas of plumbing, electrical distribution systems, total energy systems, physical distribution (elevators), solid waste, and aerobic waste treatment systems.

In plumbing, or hydro-sanitary systems, European developments have led to considerable use of new technology in ways not yet generally applied in the United States. In developing the Breakthrough criteria and selecting the system for prototype site development, we relied heavily upon European experience and technology. Our objective was not only to stimulate new technology but also to create an opportunity for the demonstration and acceptance of existing technological advances beyond the scope of our normal use.

(a) *Plumbing innovations*

For the purposes of this discussion, the term 'innovation', in Breakthrough plumbing will be applied to the materials, methods, or techniques that are not indicated as allowable in the test of the most present-day American plumbing codes. Specifically, Breakthrough includes:

(1) Plastic piping (drain-waste-vent piping; water-distributing piping).

(2) Single-stack drainage (designs derived from British single-stack drainage, and those from Swiss 'Sovent' single-stack drainage).

(3) Reduced size venting and simplified venting (designs with dry vents of less than code-size, and designs with traditional stack vents or individual vents eliminated).

(4) Prefabricated assemblages of piping (incorporation of the plumbing designs into the modular approach for the whole room or the whole house in Breakthrough appears to have much more far-reaching significance than the types of spotty prefabrication of the recent past).

A number of the plumbing innovations appearing in the Breakthrough programme appear to conflict with the 'letter' of many codes. Among the features of the criteria that have made it possible to develop a favourable reaction to a number of such innovative proposals are the following:

(1) The use of trap-seal retention and of maintenance of an effective barrier to deleterious fluid ejection as the criterion of vent-system performance, rather than the traditional ± 2.5 cm (1 in) water column pressure criterion.

(2) The use of load-supporting capability for the rims, sumps, supports, and water supply and drain connections of installed plumbing fixtures, as the criterion of the adequacy of the strength of the completed installation from the owner's and user's point of view.

(3) The identification of deleterious accumulation of spilled water in certain locations as the criterion for determination of need for floor drains or other means of disposing of such water.

(4) Criteria for avoiding deleterious ejection of detergent suds or build-up of excessive pneumatic pressures in the lower portions of sanitary d.w.v. systems.

(5) Criteria for selecting realistic hydraulic test loads for evaluating innovative d.w.v. or water-distributing systems.

(6) Criteria relating to water quality that can affect pipe sizing or selection of materials, or that can determine the need for a water-conditioning programme.

(7) A criterion that establishes a maximum and a minimum limit on available discharge rates of water outlets, under design load conditions. Although some codes exhibit a form of this criterion, experience in Breakthrough suggests that the code criteria may be largely misinterpreted or ignored.

(8) A scheme for rating relative life expectancy for the various parts of a plumbing system.

(9) Criteria for discharge effects.

(10) Among other criteria that are not widely spelled out in plumbing codes, but which are included in the Breakthrough criteria, are criteria for minimization of fouling of d.w.v. piping, criteria for system components, controlled-flow roof drainage, acoustical criteria, and fire criteria for plumbing walls, and pipe chases.

(b) *Prefabricated electrical distribution systems*

A possible 'breakthrough' in prefabricated, complete electrical distribution systems for assembly line installation in modular housing units has been developed by the General Cable Corporation at the urging of Boise Cascade. These 'spyder harnesses' consist of a central junction box or circuit breaker panel and network of predetermined legs using outlets and switches specifically designed for attachment in controlled high-volume factory assembly lines, as shown in figure 15.

These power distribution systems use conventional materials and components. The system incorporates a number of unique characteristics. For example, while the switches, outlets and other system elements are of conventional design, they are wired automatically and factory assembled in integral junction boxes ready for attachment and cover plate installation. This process is not only more economical than field fabrication of electrical distribution systems but it also appears to offer advantages in quality control, reliability and safety.

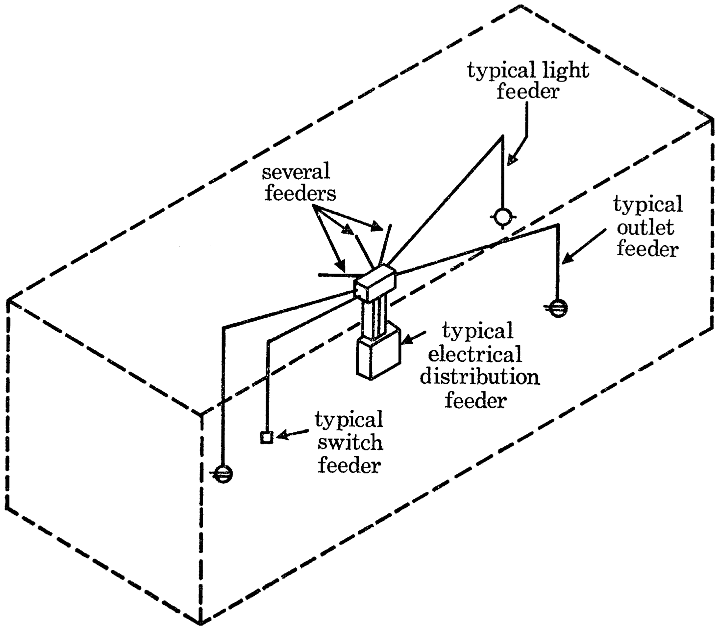

Figure 15. Typical residential wiring harness (220 V or 110 V, single phase).

(c) *Emergency electric power and heating*

Electrical codes generally require provision of emergency power sources for special facilities like police/fire, and hospitals. However, this is generally not the case for multi-family, low- or high-rise dwellings.

The blackouts we have experienced in recent years have clearly demonstrated that it would be desirable to have such back-up in a broader range of types of facilities. Therefore, the Breakthrough criteria specifically require that standby electrical power (usually generated on-site) should be provided for multi-family housing buildings containing 60 or more living units in cases where the primary power source reliability indicates a 20% annual probability of frequent (six or more per year of more than 5 min duration) or extended (6 h or more) failure of the customary power source.

These are only a few of the areas in which Operation Breakthrough is setting a performance basis for judging housing suitability. The objective is to encourage improvement and to provide a means of evaluating new concepts. Much remains to be done to make such approaches fully implementable but a good, solid start has been made.

(d) *Examples of advanced utility demonstrations for the United States*

In addition to concern for site planning and building system performance, Operation Breakthrough's prototype sites offer an opportunity to evaluate and demonstrate advanced utility systems to provide services essential to a residential community. Two of these are described below.

(i) *Total energy*

The recognized shortage of energy reserves have led to undesired conditions from both a livability and an economic standpoint. Two examples show this clearly: In Washington, D.C., and Baltimore, Maryland, no new customer can obtain natural gas service if his requirements

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exceed 85000 m³ (300000 ft³) per day. Also, the Boston Gas Company plans to import gas all the way from Algeria by tanker.

The severity of these conditions, combined with technological progress and potential cost savings, has caused a logical turn to total energy systems as a possible future solution for new development. As a result, we will be installing a full-scale total energy system at the Jersey City, New Jersey, prototype site. It will provide all electrical services, hot and cold water for space heating and cooling, and domestic hot water for 500 dwelling units as well as for shopping facilities and primary grade school facilities. Carefully designed and operated, this sytem will utilize 65 to 70% of all the heat energy in the fuel consumed, whereas large central electric generating stations usually convert only 35 to 40%.

However, unless the reduction in fuel cost for a total energy system more than offsets the higher first cost and maintenance cost as compared to the purchase of electricity from the local utility, the system would not be economically viable.

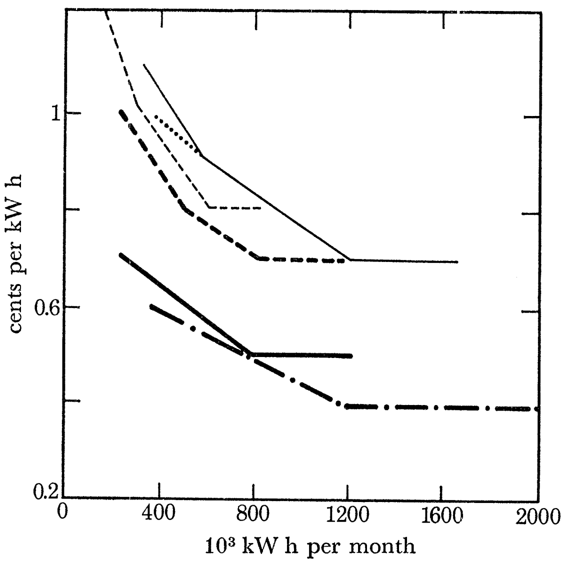

FIGURE 16. Electric rates for: —, Jersey City; · · · ·, St Louis; – – –, Indianapolis; – – –, Macon; —, Sacramento; —●—, Memphis.

Virtually all utility companies use a sliding cost scale for electric energy. The electric rates for six of the cities in which we have prototype sites, as of August 1970, are shown in figure 16. The individual home owner must pay the highest rate shown at the left of the graph, to offset both the greater distribution cost to residential customers, and also for the higher level of wasted energy that is characteristic of central generating stations. It is in these offsetting cost patterns that a total energy system may be able to attain a lower overall owning and operating cost for the whole spectrum of energy needs.

While the cost savings for individual homeowners may be significant, the dramatic savings potential becomes more obvious when the long-term energy requirements and the resulting estimates of the various savings of a total energy system are determined. Considering the use of total energy in new and redeveloped communities alone, from now until 1986, the potential saving in power generation facility capital costs is large, perhaps as high as $50000 million! Added to this would be a projected annual reduction of fuel imports by over $2500 million and a savings to the domestic consumer of some $3500 million annually in electrical costs that can now be attributed to waste energy. These numbers are based on estimates of the available market.

In addition to the specific financial savings, there would be important gains by reduced thermal pollution, reduced cooling water requirements, reduced combustion effluents – perhaps by as much as 40 % – greatly increased recycling of solid wastes, reduced sewer water volume by as much as 80 % for those units serviced by integrated utility systems, reduced noise pollution and reduced maintenance requirements for individual units.

(ii) *Solid waste disposal*

Criteria for trash and garbage removal facilities recognize the principle that to be effective for multifamily buildings such systems must be adequate, safe and convenient to all the occupants. This is reflected in Breakthrough criteria in the following provisions:

(1) Disposal facilities are required on each floor of high-rise buildings.

(2) Vertical chutes large enough to assure good operation without blockage are required.

(3) Compactors are required rather than incinerators to facilitate removal of trash from the building and to alleviate smoke pollution.

(4) Fire-safe trash rooms are required.

The most significant demonstration effort concerned with solid waste is the installation of a pneumatic vacuum trash collection (p.t.c.) system at the Jersey City site. In this system solid waste is collected at a central point through pneumatic tubes. The system is not a new technological advance since it is already in use in Sweden and the concept is used in other countries, but it is a perfect example of an innovation suited for use in the United States but as yet unaccepted. We are trying to show that such a system has advantages and can become a major item in our environmental control programme. Like the total energy system, potential financial and livability savings are considerable, and the most significant gains will come when these two systems, total energy and solid waste collection, are combined so the waste is recycled in the form of heat producing energy.

4. Conclusions

I am frequently asked whether the Operation Breakthrough effort has been justified, not only by the specific results such as those I have mentioned today, but also in relation to the priorities we face in the United States today. I think the answer is an unequivocal yes.

Were Breakthrough merely an attempt to help industry *build* more houses more efficiently, we would never have become involved with the programme. My country faces a large number of major problems that are closely related. I said earlier that a home is more than a building. So, too, is the Breakthrough programme a lot more than housing production. We are talking about communities, about recognizing the faults that are inherent in the institutions which currently dictate how we live, and where we live, and we are causing those institutions to change.

All change is not progress, but in this case I submit that the record will show that the American consumer, the home-buyer and renter, will have an expanded range of opportunities, that the individual will be better able, regardless of race or income, to find improved living conditions, and that the emphasis on housing production will have been supplemented by stronger emphasis upon quality and community in addition to assuring availability of the number of housing units we need.

I think this programme will have addressed the major economic, social and institutional issues which are currently confronting not only housing production but also life in communities across the United States. I do not for a moment think that we will have solved all of those problems, but I do believe that we will have made a major contribution to their resolution.

For the European components of the Breakthrough programme, and there are many, we are all grateful. For this opportunity to meet with you today, I am personally most honoured and appreciative.

MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES
THE ROYAL SOCIETY A
PHILOSOPHICAL TRANSACTIONS OF

FIGURE 1

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

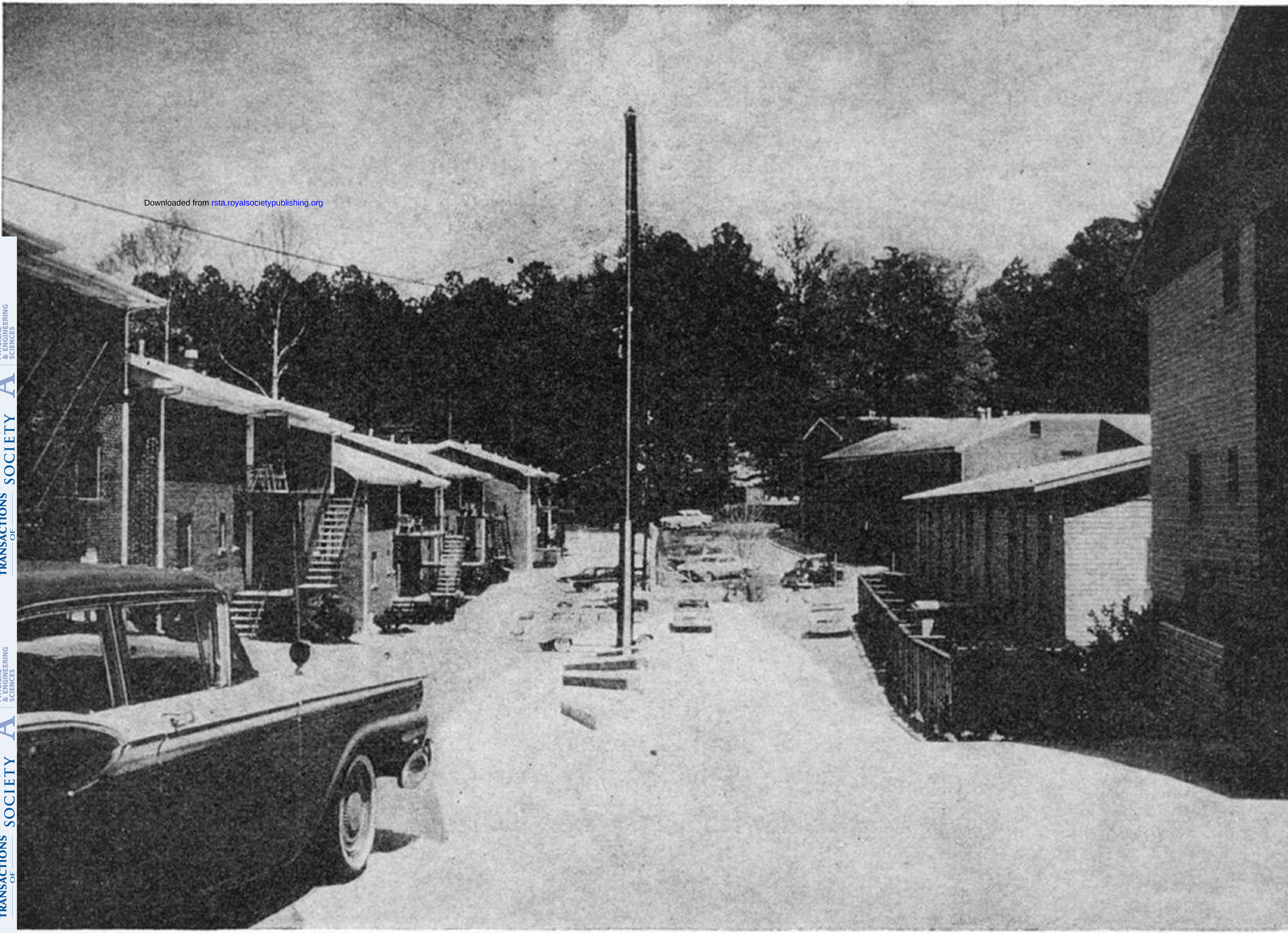

FIGURE 2

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

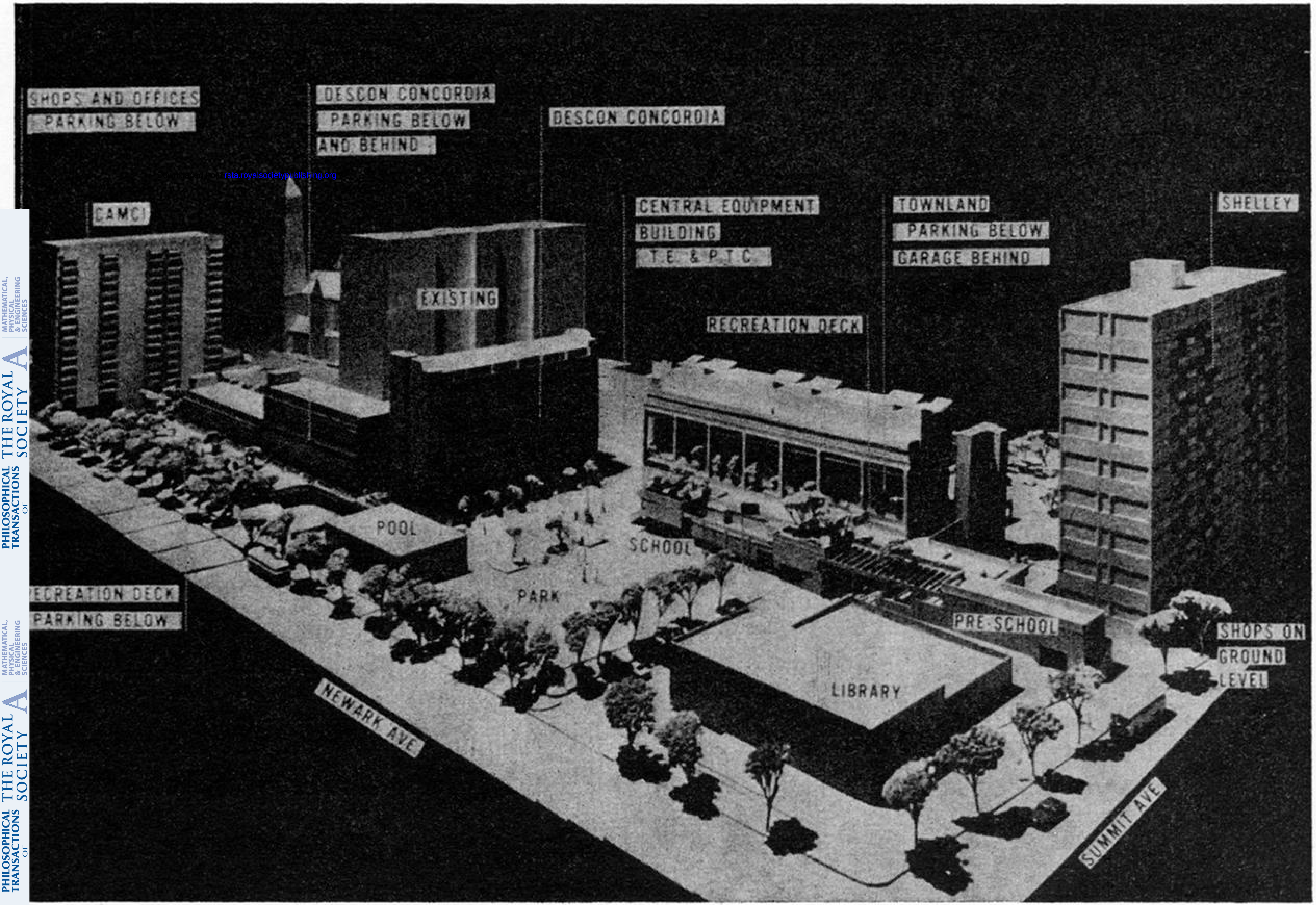
SHOPS AND OFFICES
PARKING BELOW
DESCON CONCORDIA
PARKING BELOW
AND BEHIND
DESCON CONCORDIA
CAMCI
EXISTING
CENTRAL EQUIPMENT
BUILDING
T.E. & P.T.C.
TOWNLAND
PARKING BELOW
GARAGE BEHIND
SHELLEY
RECREATION DECK
POOL
SCHOOL
ECREATION DECK
PARKING BELOW
PARK
PRE SCHOOL
SHOPS ON
GROUND
LEVEL
LIBRARY
NEWARK AVE
SUMMIT AVE

FIGURE 3

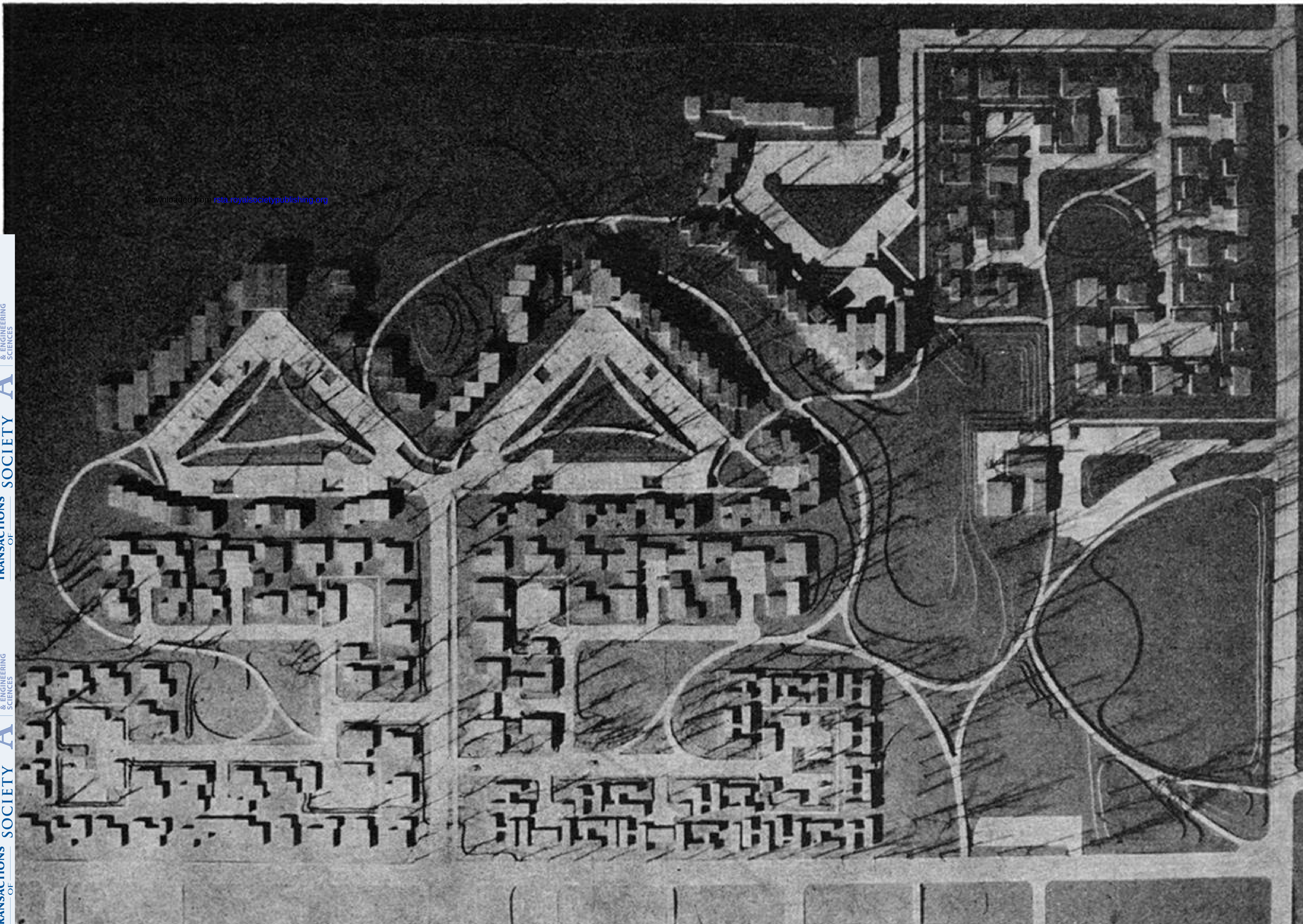

FIGURE 4

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

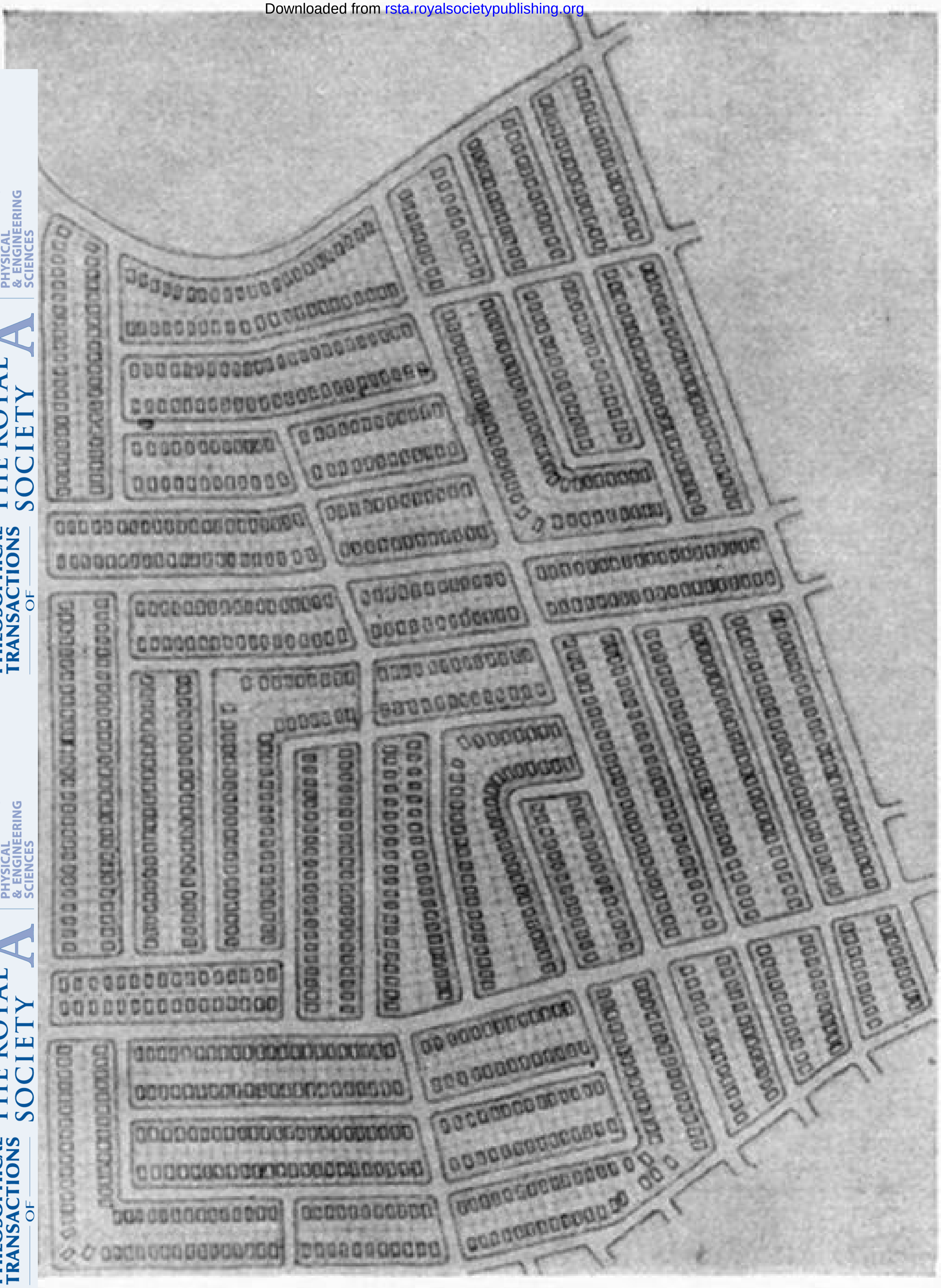

FIGURE 5

FIGURE 6

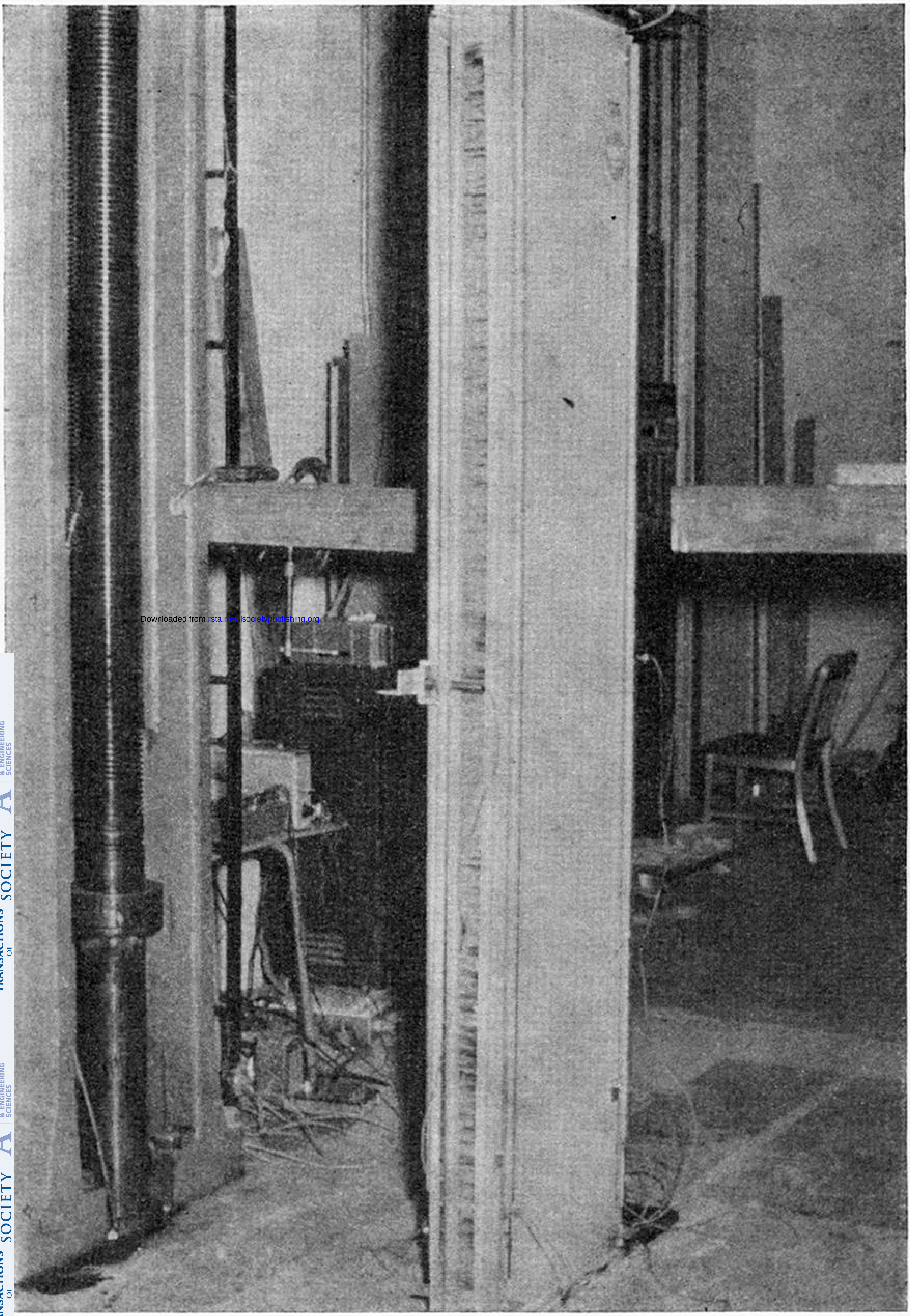

Figure 7

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

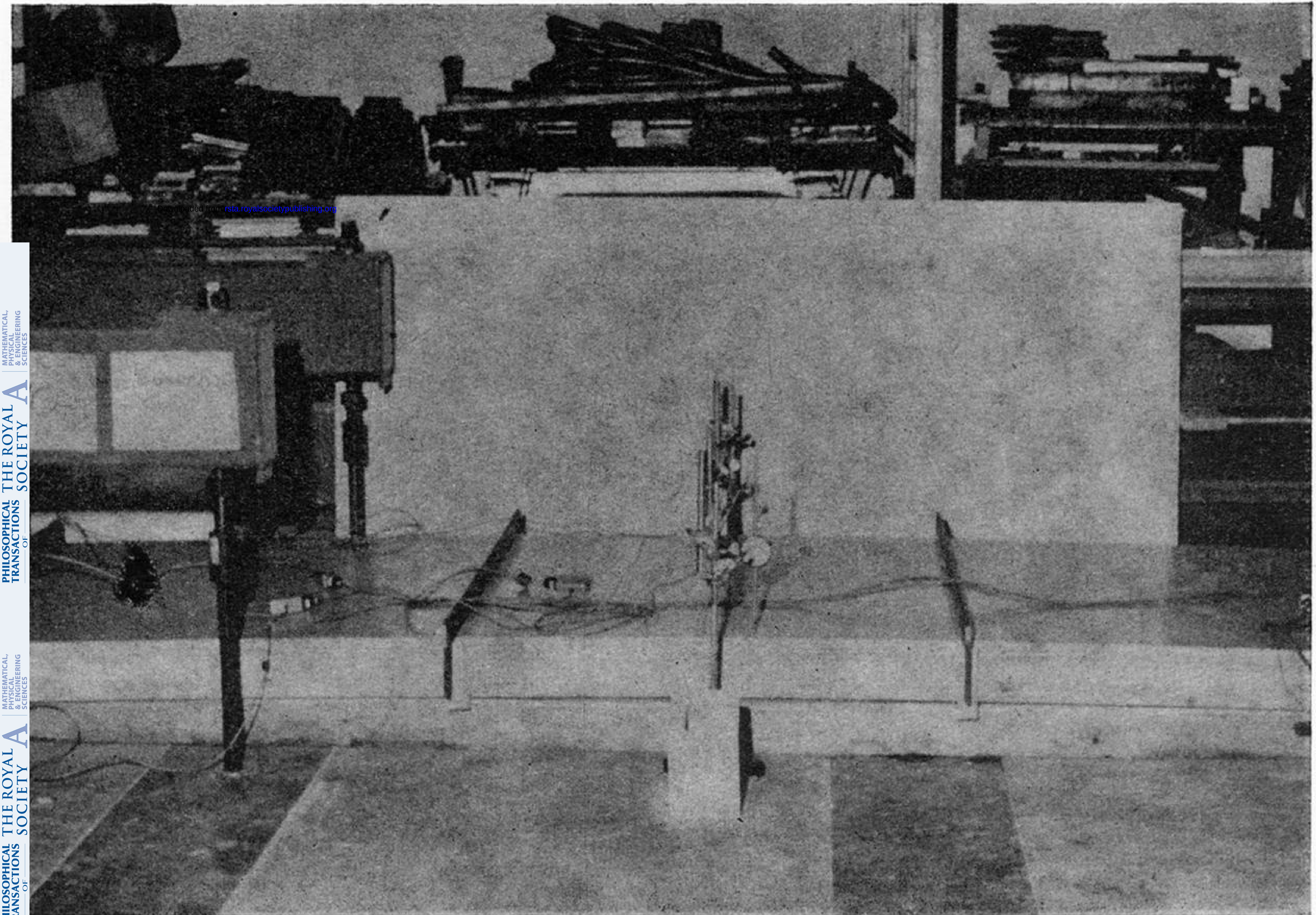

FIGURE 8

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

FIGURE 9

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES