CHAPTER IV

FINDINGS AND DISCUSSION

CHAPTER IV

FINDINGS AND DISCUSSION

Findings of the investigation as obtained on the analysis of the data collected through the survey and experiment are described and discussed in this chapter. The observations pertinent to survey have been presented in Section I followed by the experimental results which are contained in Section II.

SECTION I

Demographic characteristics of the survey sample, and age and tenure of their house are documented at the outset. Observations pertinent to values, goals and preferences held by the housewives in relation to kitchen lighting, knowledge level of housewives and their spouses regarding artificial lighting, housewife's involvement in performance of kitchen related activities and perceived level of discomfort experienced while working under artificial lighting in the kitchen are summarised. Information on family's involvement in planning and purchase of lighting - related products, sources of information for the same have been briefed next.

An attempt is made to describe the domestic kitchens with regard to the size, layout, surface reflectances, existing colour schemes and lighting systems. Also the use of artificial light in kitchen and electricity consumption is touched upon. Values computed through appropriate lighting calculations for room index, effective ceiling and floor cavity reflectances, maintenance factor and utilisation factor are presented. Data on general ambient illuminance, illuminance at selected work areas, illuminance uniformity, glare and shadow under artificial lighting are presented with relevant discussions. This is further followed by observations pertaining to daylighting. Data on daylighting included area and orientation of aperture in exterior wall(s), general ambient illuminance, illuminance at the work areas, illuminance uniformity and daylight factor.

1.0 DESCRIPTION OF THE SAMPLE

Insight into the baseline data of the sample was sought through questionnaire. Personal characteristics of the housewives and their husbands, demographic characteristics and details of their house are summarised below.

1.1 Age

The range in the age of housewives was observed to be 38 to 60 years while that of husbands was 39 to 68 years. The mean age of housewives was 45.5 years while that of husbands was 49.0 years.

Table 1 : Distribution of housewives and husbands by age

Years of age	Housewives		Husbands	
	N	%	N	%
36 – 40	26	13.61	7	3.66
41 – 45	73	38.22	36	18.85
46 – 50	71	37.17	79	41.36
51 – 55	19	9.95	44	23.04
56 – 60	2	1.05	13	6.81
60 or over	-	-	5	2.62
N. A.	-	-	7	3.66
Total	191	100.00	191	100.00
Mean	45.5		49.0	
S.D.	4.2		4.95	

The age of three-fourth and a little less than two-third of housewives and husbands respectively, ranged between 41 to 50 years. About one-tenth of the housewives belonged to the age group of 36 to 40 years. A negligible proportion of husbands belonged to the two extreme age categories (Table 1).

1.2 Education

On scrutiny of the education level of housewives and husbands, it was seen that a small proportion of husbands had low education, i.e., below graduation. More than four-fifth of the housewives and two-third of the husbands were under graduate degree / diploma holders. Nearly one-fourth of the husbands and one-tenth of the housewives had completed post graduate degree or diploma programmes. Thus, by and large the husbands had a relatively better education level than their wives (Table 2).

Table 2 : Distribution of housewives and husbands by education level

Education level	Housewives		Husbands	
	N	%	N	%
Below graduation	-	-	8	4.19
Graduate degree	165	86.39	130	68.06
Post graduate degree / diploma or / above	26	13.61	46	24.08
N. A.	-	-	7	3.66
Total	191	100.00	191	99.99

1.3 Occupation

The figures depicted in Table 3 clearly indicate the fact that majority of the housewives (73 per cent) were not gainfully employed. About one-fifth of the housewives and one half of husbands were in service, which included teachers, bank managers, accountants, self employment, laboratory technicians, drug control officers, doctors, officers at various levels in government and private organisations. About two-fifth of the husbands constituted the business group which included shop owners, factory owners, share brokers and the like. Also a negligible proportion of the husbands were involved in private practice and free lancing in professions like lawyers, management consultants, architects, doctors and the same.

Table 3 : Distribution of housewives and husbands by occupation

Occupation	Housewives		Husbands	
	N	%	N	%
No occupation (unemployed)	139	72.77	-	-
Service	39	20.42	94	49.21
Business	5	2.62	79	41.36
Private practice / Free lancing	4	2.09	4	2.09
Retired	4	2.09	7	3.66
N. A.	-	-	7	3.66
Total	191	99.99	191	99.99

1.4 Family Income

In case of majority of the families, husbands were the bread winners. Nevertheless, in approximately one-fourth of the families, housewives also contributed family income. The mean monthly family income of the selected families was estimated to be Rs.14,426.00. However, an extreme variation in the monthly family income was observed ranging from Rs.2,500.00 to Rs.60,000.00, with an S.D. of Rs.9,021.00 A little more than one-half of the families had their monthly income ranging from Rs.5,001.00 to Rs.15,000.00 and slightly more than one-fifth of the families had their monthly income ranging from Rs.15,001.00 to Rs.25,000.00 (Table 4).

Table 4 : Distribution of families by monthly income

Monthly income (Rs.)	N	%
5000 or Less	15	7.85
5001 - 10,000	59	30.89
10,001 - 15,000	43	22.51
15,001 - 20,000	31	16.23
20,001 - 25,000	11	5.76
25001 or more	12	6.28
N.R.	20	10.47
Total	191	99.99
Mean	14,426	
S.D.	9,021	

1.5 Type Of Household

The figures pertinent to nuclear family, which constituted about three- fourth of the selected sample, as seen from Table 5, suggested that nuclear family was commonly observed.

Table 5 : Distribution of families by type of household

Type of household	N	%
Nuclear	141	73.82
Joint	50	26.17
Total	191	99.99

1.6 Tenure and Age of the House

The sample of the present investigation constituted mainly those families that resided in their own houses. The data displayed in Table 6 indicate that 92 per cent of the families owned the houses that they occupied while a negligible proportion resided in rented houses.

Table 6 : Distribution of families by tenure of house

Tenure of residence	N	%
Owned	175	91.62
Rented	16	8.38
Total	191	100.00

The assessment of age of the house was carried out in terms of the number of years since that house was constructed or built. The mean age of the house was estimated to be 12. 7 years with an S.D. of 10.25. The high value of S.D. revealed a wide variation in age of the houses ranging between 1 to 58 years. Approximately one-half of the housewives reported age of their houses to be ranging from 1 to 10 years while about one-fifth informed the age to be ranging from 11 to 15 years. A little less than one-tenth of the housewives intimated their house to be as old as 26 years or more (Table 7). About 5 per cent of the housewives were unable to provide the relevant data.

Table 7 : Distribution of families by age of the house

Age (years)	N	%
5 or less	52	27.23
6 - 10	42	22.19
11 - 15	38	19.90
16 - 20	19	9.95
21 - 25	12	6.28
26 or more	18	9.42
N.R.	10	5.24
Total	191	100.01
Mean	12.7	
S.D.	10.25	

2.0 VALUES, GOALS, PREFERENCES AND KNOWLEDGE

The findings pertinent to values, goals and preferences of the housewives regarding kitchen lighting and the results of assessment of knowledge of the housewives and husbands with reference to artificial lighting are presented.

2.1 Values

The study of values aimed to measure the relative prominence of six selected values (namely, aesthetics, comfort, economy, modernism, safety and work efficiency) with regard to artificial lighting in kitchen. The scoring of data collected through the Artificial Lighting Value Scale (ALVS) was carried out as explained in the chapter on methodology and was interpreted such that the higher score on a particular value suggested stronger dominance of it over others. The possible range in score for each value was 10 to 70.

Analysis of the data revealed that about 65 to 70 per cent of the housewives were moderate scorers for all the six values on ALVS, while relatively smaller proportion of housewives belonged to either of the extreme levels by the scores on each value. It was observed that in general, the housewives did not reveal extreme disposition of favour or disfavour towards any of the six selected values. However, the computed means for each of the values indicated a relative predominance of three values : comfort, work efficiency and economy, the mean score for each being 44.4, 43.0 and 42.7 respectively. Aesthetics scored the least, in relative terms, with a mean score of 33.0 (Table 8). The value scores on comfort, work efficiency and economy of about 90 per cent of the housewives was more than 35.0, while the scores on aesthetics and modernism ranged from 25.5 to 35.0 for one-half and a little more than one-third of the housewives respectively (Table 1, Appendix V).

Table 8 : Distribution of housewives by values held by them with reference to artificial lighting in kitchen

category	Aesthetics		Comfort		Economy		Modernism		Safety		Work Efficient	
	N	%	N	%	N	%	N	%	N	%	N	%
Low	29	15.18	29	15.18	26	13.61	38	19.9	25	13.09	34	17.80
Medium	121	63.35	136	71.20	128	67.02	123	64.4	133	69.63	127	66.49
High	41	21.47	26	13.61	37	19.37	30	15.71	33	17.28	30	15.71
Total	191	100	191	99.99	191	100	191	100.01	191	100	191	100
Mean	33.0		44.4		42.7		37.4		39.5		43.0	
S.D.	7.01		5.32		6.30		6.19		5.87		5.57	

2.2 Goals

The respondents furnished details regarding their kitchen lighting related goals. The most frequently reported goals were related to efficient lighting and energy conservation. Nearly one-half of the housewives quoted "providing adequate illuminance in the kitchen" and "reduction in power consumption" as their goals. "Providing visual comfort and pleasantness to create a sense of well-being, through lighting" was cited as their goal by one-third of the housewives. A little over one-fourth of the housewives held "making fullest possible use of daylight" as their goal. Varying proportions of housewives had various other goals like "creating aesthetic appeal", "providing safe and congenial working environment", "provision for functional lighting", "having lighting that makes easy to discern colour differences in food", "lighting that facilitates the task of finding things in the cupboards", and "lighting that demands minimum maintenance" (Table 9).

Table 9 : Distribution of housewives by their kitchen lighting related goals

Sr. No.	Kitchen lighting related goals	N	%
1.	Providing adequate illuminance	97	50.79
2.	Reduction in power consumption	86	45.03
3.	Providing visual comfort and pleasantness to create a sense of well-being through lighting	64	33.51
4.	Making fullest possible use of daylight.	52	27.23
5.	Have lighting that lends an aesthetic appeal to the room	27	14.14
6.	Providing safe and congenial working conditions through lighting	21	10.99
7.	Provision of functional lighting for specific tasks	19	9.95
8.	Have lighting that makes easy to discern colour differences in food.	19	9.95
9.	Have lighting that facilitates the task of finding things in cupboards.	19	9.95
10.	Have lighting that demands minimum maintenance	18	9.42
11.	Have lighting that reflects a high standard of living and is in line with the current trends	11	5.76
12.	Provision for efficient, well located switches and concealed wiring in the kitchen.	10	5.24
13.	Have lighting that utilises the latest innovative technology in its design.	6	3.14

Housewives reported more than two goals.

The findings pertinent to values and goals held by the housewives with regard kitchen lighting projected similar picture of housewife's perception of kitchen lighting. It distinctly revealed that majority of the housewives found work-efficiency, comfort and economy as essential aspects in kitchen lighting and thus desired to achieve them by having a lighting system that would provide adequate illuminance in the kitchen and at the same time would not lead to heavy expenditure on electricity bill.

2.3 Preferences

An attempt was made to identify the preferences of housewives regarding lighting system in the kitchens. The housewives were required to indicate their choice of lighting system on a perspective sketch of a kitchen, in terms of the lighting method; type, wattage-rating and position of lamps; and use of shade. In the light of the recommendations and guidelines suggested for kitchen lighting, the responses of housewives in this regard revealed a poor choice amongst majority of the housewives. It was found that more than three-fourth of them preferred only general lighting in the kitchen amongst which 60 per cent of the housewives opted for a combination of fluorescent and incandescent lamps. Although about 70 per cent of these housewives chose to have two or more lamps in the kitchen, majority reported use of one lamp usually a 36/40 watt fluorescent lamp, quite adequate while performing the tasks in kitchen. About four-fifth of these housewives preferred to position the lamps on the walls. A preference for a combination of general and local lighting was indicated by less than one-fourth of the housewives. In general the housewives did not indicate any need for diffusers or shades for lamps in the kitchen. The choice of lighting system revealed that the idea of good quality lighting for clear visibility, safety and health was absolutely missing amongst the housewives.

Table 10 : Distribution of families by the preferences of housewives regarding lighting system in the kitchen

	General lighting			Combination of general and local lighting		
		N	%		N	%
Number of lamps				G : L		
1		44	27.33	1 : 1	26	55.32
2		109	67.70	1 : 2	15	31.91
3		8	4.97	1 : 3	3	6.38
4		-	-	2 : 2	3	6.38
Type of lamp				G : Lo		
	FL + IL	97	60.25	IL : FL	19	40.43
	FL	39	24.22	FL : FL	18	38.30
	IL	14	8.70	FL : CFL	8	17.02
	CFL	11	6.83	FL+IL : FL	2	4.26
Position of lamp				General :		
	Wall	132	81.99	Wall	25	53.19
	Ceiling	18	11.18	Ceiling	22	46.81
	Wall & Ceiling	11	6.83	Local :		
				Below cabinets	33	70.21
				Wall above task area	9	19.15
				Ceiling (directing light at work area)	5	10.64
Total		161	100.00		47	100.00

In spite of the fact that the housewives had scored moderately well on the knowledge test pertaining to artificial lighting, its applicatory aspect appeared to be very poor in the indicated choices for lighting method, type watt age and position of lamps, and use of diffusers. Also the awareness regarding use of energy saving lamps seemed to be lacking for there were a negligible proportion of housewives who chose CFL for kitchen.

2.4 Knowledge Level

One of the objectives of the study was to assess the knowledge level of the housewives and their spouses regarding artificial lighting, for which an appropriate scale was designed. The possible range of score on the knowledge scale stretched from 25 to 50, higher score being indicative of higher level of knowledge.

Table 11 : Distribution of housewives and husbands by their knowledge level pertaining to artificial lighting

Knowledge Level	Housewives		Husbands	
	N	%	N	%
Low	33	17.28	33	17.93
Medium	125	65.45	124	67.39
High	33	17.28	27	14.67
Total	191	100.01	184*	99.99
Mean	37.6		39.1	
S. D.	4.21		4.14	

* The husbands were not alive in 7 families

On the basis of the mean scores and S.D. on the knowledge test, majority of housewives and husbands were categorised in the moderate group. More or less the same proportion exhibited high and low knowledge level. The mean knowledge score of housewives and husbands were estimated to be 37.6 and 39.1 respectively (Table 11). A little more than two-third of housewives and three-fourth of husbands earned scores ranging from 36 to 45. The data pertinent to the knowledge level indicated that a relatively greater proportions of low scorers and high scorers were amongst the housewives and husbands respectively (Table 2, Appendix V). Though the housewives and their spouses revealed relatively higher scores on knowledge test, there were a few aspects that were eliminated in the standardisation process of the knowledge test on which they had little knowledge. The aspects on which the housewives and their husbands lacked knowledge were concepts of illuminance and luminance contrast between the task and its surrounding ; interpretation of information given on the lamps about colour temperature, colour of light and lamp wattage ; and awareness regarding energy saving lamps like compact fluorescent lamps (CFL) and unit cost of electricity.

3.0 HOUSEWIFE'S INVOLVEMENT IN PERFORMANCE OF KITCHEN RELATED ACTIVITIES AND DISCOMFORT EXPERIENCED

Findings pertinent to the involvement of housewives in performing various kitchen related activities like pre-preparation, cooking, cleaning up and dishwashing are presented here. The discomfort reported by the housewives while working in the kitchens under existing artificial lighting, is discussed.

3.1 Housewife's Involvement in Performance of Kitchen-Related Activities

The findings projected in Table 12 reflect that pre-preparation and cooking tasks were carried out solely by the housewives in more than three-fourth of the families. The cleaning up job in kitchen was carried out by 43.98 per cent of the housewives, while merely one-fifth of the housewives themselves performed the task of washing the dishes. The dishwashing was done by the servants in 73.3 per cent of the houses.

Table 12 : Distribution of Housewives by involvement in performance of kitchen- related activities

	Pre-preparation		Cooking		Cleaning-up		Dish- washing	
	N	%	N	%	N	%	N	%
Housewives	146	76.44	169	88.48	84	43.98	34	17.80
Housewives along with other family members and/or servants	21	10.99	11	5.76	15	7.85	8	4.19
Other Family Members	16	8.38	6	3.14	28	14.66	9	4.71
Servants	8	4.19	5	2.62	64	33.51	140	73.30
Total	191	100.00	191	100.00	191	100.00	191	100.00

3.2 Perceived Level of Discomfort

It was thought worthwhile to gain insight into the perceived level of discomfort experienced by the housewives while working under existing artificial lighting in the kitchen. The physical, mental and functional aspects of discomfort were assessed using a check list constituting statements with response categories of "Yes" or "No" with a possible range of 0 to 24. The responses were then quantified and scored. The scores were interpreted such that a higher score indicated a higher perceived level of discomfort and vice versa. A little less than one-half and one-third of the housewives earned discomfort score ranging from 1 to 4 and 5 to 8 respectively with a mean score of 4.6 (Table 13). It is to be noted that apparently the mean score on the set of 24 statements revealed a low discomfort level amongst the housewives while working under artificial lighting in the kitchen. However, discomfort scores on individual items on the check list projected a more clear picture. While the responses on majority of the items on the checklist were scattered, there were a few items that had earned concentrated responses for discomfort. This gave rise to the need to get an insight into these items.

It was found that working in kitchen for a long period of time was strenuous to eyes for almost one third of the housewives. A little less than one fourth of the housewives experienced headaches, feeling of tiredness and irritation while working in the kitchen. With regard to functional discomfort, around one-fourth of the housewives expressed difficulty in locating items stored within the storage cabinets and in cleaning utensils especially with intricate designs like glass-ware with etched designs. It was also found that one-fourth of the housewives did not find the kitchen environment aesthetically pleasing, while one-fifth found their kitchens to be dull which did not stimulate them to work in the kitchen (Table 3, Appendix V).

However, when the housewives were asked to mark their satisfaction regarding existing artificial lighting conditions in their kitchens on a three point scale, majority (86.54 per cent) reported to be satisfied and 7.69 per cent indicated a neutral response. In spite of the discomfort experienced while working under artificial lighting in the kitchens, not many housewives were found to be dissatisfied. (Table 4, Appendix V).

Table 13 : Distribution of housewives by scores on discomfort experienced while working under existing artificial lighting in the kitchen

Discomfort scores	N	%
Less than 1	25	13.1
1 - 4	83	43.5
5 - 8	63	32.9
9 - 12	15	7.9
13 or more	5	2.6
Total	191	100
Mean	4.5	
S.D.	3.57	

4.0 SOURCES OF INFORMATION REGARDING LIGHTING PRODUCTS AND INVOLVEMENT OF FAMILY IN ITS INSTALLATION PLAN AND PURCHASE

Sources of information regarding lighting products and the sources that influenced choices of the housewives have been investigated. Further, the involvement of members of the family in planning installation and purchase of wiring, switches, lamp-holders and lamps has also been studied.

4.1 Sources of Information Regarding Lighting Products

Advertisements on television and radio were reported as sources of information regarding lighting products by 70 per cent of the housewives. However, only one-half of the housewives amongst these 70 per cent were found to be influenced by such advertisements in their choices of various lighting products. It was observed that visits to the market and interaction with other family members, relatives and friends served as sources of information for about 45 per cent of the housewives, amongst which 85 to 90 per cent were influenced in their choices of lighting products (Table 14).

The findings clearly indicate that even though advertisements on television and radio were the most popular sources of information on lighting products, the choices for the same were mainly influenced by visits to the market and interaction with other family members, relatives and friends.

Table 14 : Distribution of housewives by sources of information and sources that influenced their choices of lighting products

Scores	Sources of information N=191		Sources that influenced the choices N=191	
	N	%	N	%
1. Advertisements on audio visual media like television and radio	134	70.16	69	36.13 (51.49)
2. Advertisements in print media like magazines and news papers	96	50.26	56	29.32 (58.33)
3. Other family members, relatives and friends	90	47.12	76	39.79 (84.44)
4. Visits to market	83	43.46	76	39.79 (91.57)
5. Books on Interior decoration / design	51	26.70	30	15.71 (58.82)

More than one source was reported

4.2 Family Involvement In Installation Plan And Purchase Of Lighting Products

Involvement of family members in planning installation and purchase of switches and lampholders for the kitchen was found in about 25 per cent and 50 per cent of the families, respectively. In three-fourth of the families, the installation of switches and lampholders was reported to have been carried out solely by the

Table 15 : Distribution of families by their involvement in installation plan and purchase of lighting products

	Wiring System				Switches				Lamp Holders				Lamps			
	Planned by		Purchased by		Planned by		Purchased by		Planned by		Purchased by		Planned by		Purchased by	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Professionals involved in house construction	163	85.34	134	70.16	139	72.77	92	48.17	132	69.11	79	41.36	120	62.83	61	31.94
Family members	19	9.95	48	25.13	35	18.32	82	42.93	39	2042	91	47.64	53	27.75	123	64.40
Combined	-	-	-	-	8	4.19	8	4.19	11	5.76	12	6.28	9	4.71	5	2.62
N.R.	9	4.71	9	4.71	9	4.71	9	4.71	9	4.71	9	4.71	9	4.71	2	0.01
Total	191	100	191	100	191	100	191	100	191	100	191	100	191	100	191	100

professionals like builders, contractors, architects and electricians, who were involved in the construction of the houses. The proportion of family involvement was still less in planning of installation and purchase of wiring. However, a relatively higher involvement of the members of the family i.e., approximately 30 per cent and 65 per cent was observed with regard to installation plan and purchase of lamps in the kitchen respectively. (Table 15). In general, it was observed that very low involvement of members of the family existed in relation to installation plan and purchase of wiring, switches, lamp holders and lamps. Family's participation in decisions related to location of switches and lighting fixtures, type, number and wattage rating of lamps, light distribution and the like was very low.

5.0 DESCRIPTION OF KITCHENS AND KITCHEN LIGHTING

The description of domestic kitchens is presented with regard to size, layout, surface reflectances, existing colour schemes and lighting systems. Findings on room index, effective ceiling and floor cavity reflectances, maintenance factor and utilisation factor, as computed through appropriate lighting calculations are described in the ensuing pages.

5.1 Size of Kitchens

The size of kitchens surveyed were identified in terms of small, medium and large. The total kitchens were categorised into quartiles, by their floor area. A kitchen was considered as small if it was found to lie below the first quartile, while it was classed as large if it was found to lie above the third quartile. The mean values for floor area and height of small, medium and large size kitchens were 5.79 m^2 and 2.74 m, 8.82 m^2 and 2.85 m and 13.08 m^2 and 2.92 m respectively (Table 16). With regard to the total kitchens, the mean values for floor area and height were estimated to be 9.10 m^2 and 2.85 m respectively. Further, the mean height of work surface in the 208 kitchens was estimated to be 0.81 m with an S.D. of 0.05.

Table 16 : Distribution of kitchens by their sizes

Size of kitchen	N	%	Floor area (m^2)				Height (m)			
			Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
Small	52	25	5.79	0.78	4.20	7.01	2.74	0.38	1.83	3.80
Medium	104	50	8.82	1.16	7.02	11.04	2.85	0.29	1.77	3.90
Large	52	25	13.08	1.72	11.06	18.24	2.92	0.35	2.05	4.07
Total	208	100	9.13	2.89	4.20	18.24	2.85	0.31	1.77	4.07

5.2 Kitchen Layout

In a little more than two-third of the kitchens, platform was laid in L-shape while one-fourth of the kitchens constituted one wall layout (Table 17). Amongst the L-shape kitchens, it was observed that in 40 per cent and 34 per cent, the sink was fixed on the shorter and longer arm respectively while it occupied the corner in 25 per cent of such kitchens. Sink was not found among a negligible per cent of kitchens.

For the study purpose, three major work areas were identified in each kitchen, namely, cooking area, pre-preparation area and sink area. In cases where pre-preparation activity was reported to be carried out at more than one part of the work platform, the more frequently used one was considered for purpose of analysis. With regard to the physical arrangement of three work areas, it was found that the most commonly observed placement in 64.42 per cent of kitchens was that the pre-preparation area was sandwiched between the cooking area and the sink. In one-fourth of the kitchens, there was an overlap of pre-preparation area and cooking area with the sink adjacent to it. The placement of work areas varied in the remaining 10 per cent of the kitchens.

The wall cabinets were found to be existing above the work platform in a little less than one-third of the kitchens while in more than two-third cases there were no cabinets placed above the platform. The refrigerator was installed within the kitchen in a little more than one-half of the residential units while in other cases the refrigerator was placed in living room or dinning room or bed room or passage way. Further, it was found that the dining area was located in the kitchen premises in only 13.9 per cent of the houses.

Table 17 : Distribution of kitchens by the layout of work platform

Layout of work platform	N	%
L - Shape	140	67.30
One – Wall	51	24.52
U - Shape	14	6.73
Corridor	1	0.48
Penninsula	1	0.48
Irregular	1	0.48
Total	208	99.99

5.3 Colour Schemes and Surface Reflectances

Colour, in context to its reflectance potentiality influences the utilisation factor of light. An attempt was made to study the existing colour schemes with predominant hue used in the major interior space of kitchens, namely, the walls, ceiling and floor. Analysis of data on existing hues in interior space revealed that neutral colour scheme was the most popular amongst the various colour schemes observed in the kitchen (Table 18).

Table 18 : Distribution of kitchens by existing colour schemes

	Colour schemes		N	%
1.	Neutral colour scheme		60	28.85
2.	Monochromatic colour schemes *			
	Primary hue :	Yellow	43	20.67
		Red	21	10.10
		Blue	16	7.69
	Secondary hue :	Orange	28	13.46
		Green	26	12.50
		Violet	1	0.48
3.	Analogous colour schemes*		6	2.88
4.	Complementary colour schemes*		2	0.96
5.	Unidentified schemes		5	2.40
	Total		208	99.99

* neutral hues on ceiling and floor

The walls of the kitchens were found in white colour in more than one-third of the houses, amongst which approximately 50 per cent of the kitchens had a combination of white washed walls and ceiling, and grey coloured floor, while 30 per cent had walls, ceiling and floor in white colour. (Table 6, Appendix V).

Amongst the chromatic colour schemes, monochromatic colour scheme was commonly observed in the kitchens with predominant primary hues being yellow (20.67 per cent), red (10.10 per cent) and blue (7.69 per cent) and secondary hues as orange (13.46 per cent) and green (12.50 per cent). These hues in general were found in combination with neutral hues. In most of these kitchens, ceiling and floor were found in white and grey colour respectively blended with any one of the chromatic hues on the walls. (Table 6, Appendix V). Neutral hue was the most popular colour for the work platform in kitchens with predominance of grey (42 per cent), white (12 per cent) and black (12 per cent) (Table 5, Appendix V). However, most of the kitchens did not reveal an aesthetically and/or functionally appealing combinations of colours and there was no basis by which one could decide upon the existing colour schemes.

Further, the reflectances of the kitchen surfaces were studied in terms of their value ranging from the highest value i.e., white to the lowest value i.e. black depending on the proportion of white and black in it. The value of the hue used on the room surfaces on which the light rays strike has got a bearing on the amount of light reflected from that surface. On the basis of the reflectances of the various value levels of the hue the surfaces were categorised as white or very light (r=0.7), light(r=0.5), medium(r=0.3) and dark(r=0.1) (Philips Lighting Course). A large number of kitchens

(30 per cent) were observed in hues with white / very light and medium values with regard to the major interior space. Approximately similar proportion of the kitchens had their surfaces with white / very light and light values. Other combinations found were hues in white / very light, light and medium values ; purely white / very light values ; white / very light and dark values ; and still more in negligible proportions (Table 19). The existing values in context to the respective room surfaces i.e., the wall, ceiling and floor has been displayed in Table 7, Appendix V.

Table 19 : Distribution of kitchens by surface reflectances

Reflectance of kitchens surfaces	N	%
White / very light and medium	62	29.81
White / very light and light	57	27.40
White / very light, light and medium	27	12.98
White / very light	21	10.10
White / very light and dark	11	5.29
Light and medium	8	3.85
White / very light, light and dark	8	3.85
Light	7	3.37
White / very light, medium and dark	4	1.92
Light and dark	2	0.96
Light, medium and dark	1	0.48
Total	208	100.01

White/very light : r = 0.7, Light : r = 0.5 , Medium : r = 0.3 , Dark : r = 0.1

A combination of white / very light coloured walls and ceiling with floor in medium value was observed in a little less than one-fifth of the kitchens. White / very light coloured walls and ceiling with floor in light value; light coloured walls and white / very light coloured ceiling with floor in medium value; walls, ceiling and floor in white or very light colours; walls and floor in medium value with white / very light coloured ceiling were the other commonly observed combinations in the kitchens.

5.4 Lighting System

The success of a lighting design depends on the suitability of lumen output; number, location and mounting height of light points and luminaire type, its light distribution characteristics and maintenance condition. An assessment of existing lighting system in the kitchens was considered to be an essential aspect of the present investigation.

It was observed that a little less than two-third of the kitchens were equipped with a bare fluorescent lamp providing general lighting. More than one-fourth of the kitchens were provided with two light sources amongst which a combination of fluorescent and incandescent lamps was predominantly found (Table 20). However, in 97 per cent of the kitchens, the routine tasks were reported to be performed under a single source of light, generally using the fluorescent lamp. In more than 90 per cent of the kitchens with two light sources, the second light source was found as either not been used at all or was used for a very short duration of time. This light source, in general, served as an alternate source in case of failure of the primary light source. Also because of the "instant start" feature of incandescent lamp, it was used for short frequent visits in the kitchen. The popularity of fluorescent lamp in residential kitchens was also reported by Desai (1977) and Thakkar (1989) According to Bandyopadhyay (1999), fluorescent lamp was introduced in Indian market immediately after the independence and by the end of the fifties its application became prominently visible in homes. However, a contrary finding was revealed by Saxena, Kumar and Pal (1980) who reported that tungsten incandescent lamp served as a source of light in 94 per cent of the kitchen. This disparity can be accounted for by the fact that the locale of their study was a small town where the drive to shift from use of incandescent lamps to fluorescent lamps might not have gained momentum.

The light source(s) under which the routine kitchen activities were carried out were identified as the primary source(s) of light. By and large the mode of installation of the primary source of light was surface mounting and the mean mounting height from the reference surface was 1.61 m (Table 8, Appendix V). The most commonly observed power rating of these lamps in the kitchen was 36 w/40w. (Table 9, Appendix V).

The light from the primary source (s) of light struck the cooking and pre-preparation area from the left-hand side of the worker in about one-fourth of the kitchens and from the front of the worker in a little less than one-fifth of the kitchens. In one-fourth of the kitchens the light source was mounted to the right-hand side of the worker when positioned at either cooking or pre-preparation or sink area, while the light struck the three respective work areas from behind the worker in less than one-fifth of the kitchens (Table 10, Appendix V).

Table 20 : Distribution of families by existing lighting system in the kitchen

Description of the lighting system	N	%
One light source installed for general lighting		
bare $FL_{(P)}$	131	62.98
$FL_{(P)}$ with acrylic diffuser	2	0.96
bare $IL_{(P)}$	10	4.81
bare $CFL_{(P)}$	1	0.48
Two light sources installed for general lighting		
bare $FL_{(P)}$ + $IL_{(S)}$	45	21.63
$FL_{(P)}$ with acrylic diffuser bare $IL_{(S)}$	1	0.48
bare $FL_{(P)}$ + $FL_{(P)}$	3	1.44
bare $FL_{(P)}$ + $CFL_{(S)}$	1	0.48
bare $IL_{(P)}$ + $IL_{(S)}$	3	1.44
bare $IL_{(P)}$ + $FL_{(S)}$	2	0.96
bare $CFL_{(P)}$ + $IL_{(S)}$	1	0.48
Three/four light sources installed for general lighting	1	0.48
bare $FL_{(P)}$ + $IL_{(S)}$ + $IL_{(S)}$	3	1.44
bare $FL_{(P)}$ + $FL_{(S)}$ + $IL_{(S)}$	1	0.48
bare $FL_{(P)}$ + $CFL_{(S)}$ + $IL_{(S)}$	1	0.48
bare $FL_{(P)}$ + $FL_{(P)}$ + $IL_{(S)}$	1	0.48
bare $FL_{(P)}$ + $FL_{(P)}$ + $FL_{(S)}$ + $IL_{(S)}$	1	0.48
Three light sources installed for a combination of general and local (direct) lighting		
bare $FL_{(P)}$ + $FL_{(P)}$ + $IL_{(P)}$ + $IL_{(S)}$	1	0.48
Total	208	100.0

FL : fluorescent lamp, IL : incandescent lamp, CFL : compact fluorescent lamp
(P) : primary source of light, (S) : secondary source of light

With regard to the maintenance condition of the lamps, in 68.3 per cent of the kitchens the lamps were found to be moderate in maintenance (moderately dirty), implying that the presence of dust, smoke and grease on the lamp was found in a moderate level. In more or less equal proportion of kitchens, the lamps were found to be in well maintained (clean) and ill maintained (decidedly dirty) conditions of maintenance respectively (Table 11, Appendix V).

5.5 Use of Artificial Lights During Day and Night Time

The respondents furnished information on the time duration for which their artificial lights were used during day and night-time in the kitchens. It was found that in about three-fourth of the kitchens artificial lights were used for 1 to 2 hours per day during daytime and for 2 to 5 hours per day during night time. The total time duration of use of artificial lights ranged from 3 to 5 hours per day in a little over one-half of the kitchens. The mean time for use of artificial lights in kitchens was estimated as 4:7 hours with an S.D. of 1.8 (Table 21).

A relatively high value of S.D. revealed a wide variation amongst the kitchens in the amount of time for which artificial lights were used. This could be attributed either to strong variation in the availability of daylight in these kitchens or to high differences in the working patterns of the housewives in performing the kitchen activities. An increased use of artificial lights could be due to lack of availability of daylight in the kitchens in contrast to the kitchens having greater accessibility to daylight. Further, depending upon the working pattern of the housewives the use of artificial light may drastically increase in kitchen where the meal preparation related activities are concentrated during night hours. The working pattern of the housewives may vary with their habits, preferences, employment status, family set up and cultural background.

Half of the respondents reported use of artificial light for 5 hours or more, the maximum being 13 hours. Artificial lighting supplemented daylight in 87 per cent of the sample. Thus a substantial use of artificial lighting was observed in majority of the kitchens under study. These observations stress the fact that need for efficient lighting through artificial sources cannot be ignored.

Table 21 : Distribution of families by use of artificial lights during day - time and night - time in kitchens

Use of artificial lights (in Hours)	Day time		Night time		Total time	
	N	%	N	%	N	%
Nil	28	13.46	-	-	-	-
1	95	46.15	5	2.40	-	-
2	54	25.96	37	17.79	9	4.33
3	20	9.62	75	36.06	28	13.46
4	3	1.44	55	26.44	65	31.25
5	4	1.92	24	11.54	48	23.08
6	2	0.96	12	5.77	22	10.58
7	-	-	-	-	16	7.69
more than 7	1	0.5	-	-	20	9.62
Total	208	100	208	100	208	100
Mean	1.38		3.31		4.69	
S. D.	1.23		1.12		1.83	

5.6 Consumption of Electricity

The data pertaining to consumption of electricity was gathered from the records of bills that were maintained by the families. Information on power consumption of the families during a span of six month was utilised to compute the average monthly consumption in terms of the units of electric power consumed. Proportion of electric power consumption through lighting in the kitchen to the total consumption was worked out. The mean values of units of electric power consumed per month by families in their homes and specifically in the kitchens were 171.9 and 7.0 respectively (Table 27). The findings revealed that the units of electric power consumed for kitchen lighting was less than $1/25^{th}$ part of the total electricity consumed in the homes. The cost of electricity was calculated at the rate of Rs. 3.75 per unit. For the purpose of computation of expenditure on electric power a month has been taken as 30 days. In monetary terms, a family spent approximately Rs. 26.25 per month on kitchen lighting out of an expenditure of Rs. 645.00 on total electricity bill, i.e. the amount spent on kitchen lighting accounted for only 4 per cent of the total amount spent on electricity by an average family.

In contrast, the monthly monetary cost incurred for operating a refrigerator (240 watt) for 18 hours per day and, an iron (700 watt), a geyser (2000 watt) and an automatic washing machine (500 watt) each for one hour per day is Rs. 129.60, Rs. 78.75, Rs. 225.00 and Rs.56.25 respectively. A comparative analysis reveal that the financial expenditure for lighting in kitchen was negligible to save fuel bill at the cost of work efficiency and health.

Table 22 : Distribution of families by units of electric power consumed

	Monthly electric power consumption for all purposes (kWh)	Monthly electric power consumption for kitchen lighting* (kWh)	
N	135**	135	208
Mean	171.9	7.0	7.4
S.D.	81.11	2.71	2.98
Minimum	17.5	2.3	2.3
Maximum	612.5	18.7	18.7

* inclusive of ballast wattage (12 watt) in case of fluorescent lamps

** six months record on power consumption (electricity bills) was funished by 135 housewives.

5.7 Room Index (K)

Room index (K) served as a proportionality factor accounting for the effect of room proportions upon the utilisation factor. It was determined by the utilising data on room dimension and the mounting height of lamps in each kitchen. The standard classification given by I.E.S. (1954) was used for categorising findings pertinent to K. It was found that in a little more than two-third of the kitchens, the K ranged between 0.70 to 1.11 (Table 23). The mean value for K was 0.98 with an S.D. of 0.40. The total range in the same was observed to be 0.42 to 3.68. The distribution of the sample by mean and S.D. indicated that about 90 per cent of kitchens belonged to the moderate category by K, while a very small proportion of kitchens belonged to either of the extreme categories (Table 12, Appendix V).

Table 23 : Frequency and percentage distribution of kitchens by room index

Room index	N	%
0.69 or less	24	11.54
0.70 - 0.89	76	36.54
0.90 - 1.11	66	31.73
1.12 - 1.37	28	13.46
1.38 - 1.74	6	2.88
1.75 - 2.24	3	1.44
2.25 - 2.74	1	0.48
2.75 - 3.49	3	1.44
3.50 - 4.49	1	0.48
4.50 or more	-	-
Total	208	100.00
Mean	0.98	
S. D.	0.40	

5.8 Effective Ceiling and Floor Cavity Reflectance (ρ_{CC} and ρ_{FC})

Effective cavity reflectance represented a combined effect of wall and ceiling reflectances. On the other hand, effective floor cavity reflectance represented a combined effect of wall and floor reflectances. The ρ_{CC} and ρ_{FC} are obtained by interpolating ceiling cavity ratio with ceiling and wall reflectances, and floor cavity ratio with wall and floor reflectances respectively with the aid of a standard table (IES, 1966). The ceiling cavity ratio accounts for the effects of room proportion above the luminaire plane while the floor cavity ratio accounts for these effects below the work plane.

Table 24 : Frequency and percentage distribution of kitchens by per cent effective ceiling and floor cavity reflectance

Effective cavity reflectance (%)	Ceiling		Floor	
	N	%	N	%
20 or less	1	0.48	45	21.63
21 - 30	4	1.92	74	35.6
31 - 40	22	10.58	42	20.19
41 - 50	43	20.67	32	15.38
51 - 60	67	32.21	15	7.21
61 - 70	71	34.13	-	-
Total	208	100.00	208	100.00
Mean	54.07		30.23	
S. D.	11.04		11.98	

The ρ_{CC} and ρ_{FC} of the kitchens ranged from 12 to 70 and 6 to 56 respectively. It was observed that two-third of the kitchens had ρ_{CC} ranging from 51 to 70 and a little more than one-third of the kitchens had ρ_{FC} ranging from 21 to 30. The mean ρ_{CC} and ρ_{FC} was found to be 54.07 and 30.23 with S.D. of 11.04 and 11.98 respectively (Table 24). The high values of ρ_{CC} could be explained by the existing colour on the ceiling, which was observed to be white in a little less than 90 per cent of the kitchens. In contrast, 60 per cent of the kitchens had floors in medium to dark grey colour which could account for the low values of ρ_{FC}. Further, categorisation on the basis of mean and SD revealed that the majority were in the medium group lying between 45 to 65 per cent and 18 to 42 per cent in the case of p_{CC} and p_{FC} respectively. More or less similar proportion of kitchens were identified in low and high categories of p_{CC} and p_{FC} (Table 13, Appendix V).

5.9 Maintenance Factor (MF)

Maintenance factor was considered as a variable worth studying as it accounted for the overall depreciation in light caused by an interplay of room index, lamp type, luminaire type, distribution of luminance flux from the luminaire/s (luminaire flux fraction), burning hours, elapsed time between cleaning cycle and maintenance condition of room surfaces and lamp(s) / luminaire(s). MF was computed as a product of lamp lumen maintenance factor (LLMF), lamp survival factor (LSF), luminaire maintenance factor (LMF), and room surface maintenance factor (RSMF). The individual values for each of the four factors were obtained from standard tables (Philips Lighting Manual, 1993) by feeding the appropriate data collected through field observations.

In one third of the kitchens, the MF ranged between 0.85 to 0.89. The mean MF was found to be 0.83 with an S.D. of 0.08 (Table 25). The analysis of data, showed that a little more than two-third of the kitchens were moderately maintained while equal proportions of the kitchens belonged to the low and high category by MF (Table 14, Appendix V). In spite of the fact that majority of the kitchens had fluorescent lamps as the source of light, the maintenance factor was found to be moderate. The reason could be that in approximately 70 per cent of the kitchens the lamps were bare and were in somewhat dirty conditions. It was found that in 40 per cent of the kitchens, the lamps were cleaned once in three months while in a little less than 20 per cent of the kitchens the cleaning of lamp was carried out once in six months. Also the major room surfaces, namely, the walls, ceiling and floor were found in moderately dirty conditions in about one-half of the kitchens. Further, the number of hours the lamp/s was/were burned ranged between 1000 to 3000 hours in about 60 per cent of the kitchens and still more in the remaining kitchens.

Meal preparation activities in Indian kitchens are characterised by enormous emission of smoke, greasy vapours and fumes leading to deposition of dirt and dust on the lamps / luminaires and the room surfaces. Exhaust fans are rarely an integral part of kitchen accessories and hence the emissions harbour themselves on any surface and that of lamps and luminaires being of significance as far as MF is concerned. Lack of awareness and negligence on the part of the families regarding the light loss due to accumulated dirt on lamps and other surfaces could also be identified as a contributory factor for moderately maintained lighting system and interior. Hence, it throws a light on the need to educate families, create awareness, develop concern and bring about change in the attitute towards lighting.

Table 25 : Distribution of kitchens by maintenance factor

Maintenance factor	N	%
Less than 0.70	10	5.29
0.70 - 0.74	17	8.99
0.75 - 0.79	28	14.81
0.80 - 0.84	31	16.40
0.85 - 0.89	62	32.80
0.90 - 0.94	41	21.69
Total	189*	100

* LLMF and LSF for 2 cases with CFL installed was not known.
NR=19 cases.

5.10 Utilisation Factor (UF)

It was thought essential to ascertain the proportion of generated lamp lumen that reached the work surface by computing the utilisation factor, which is the measure of the overall efficiency of the existing lighting system. For the present investigation, UF was determined by computing the ratio of the average ambient general illuminance per m^2 to the lamp lumen.

Table 26 : Distribution of kitchens by utilisation factor

Utilisation factor	N	%
0.09 or less	6	2.88
0.10 - 0.14	33	15.87
0.15 - 0.19	53	25.48
0.20 - 0.24	48	23.08
0.25 - 0.29	22	10.58
0.30 - 0.34	19	9.13
0.35 - 0.39	12	5.77
0.40 - 0.44	5	2.40
0.45 - 0.49	3	1.44
0.50 - 0.54	3	1.44
0.55 or more	2	0.96
N.A.	2	0.96
Total	208	100.00
Mean	0.23	
S. D.	0.11	

* LLMF and LSF for 2 cases with CFL installed was not known.

The mean value for UF was 0.23 and the range in the same was estimated to be 0.05 to 0.91. In more than one-half of the kitchens the UF of lighting system was observed to range from 0.15 - 0.29 (Table 26). These low values of UF could be accounted for losses due to either the effects of room index or the reflectance of room surfaces or light loss due to absorption of light in the lamps / luminaires. However, relatively in a very small proportion of kitchens (approximately 3 per cent) the UF was 0.60 or more.

6.0 QUANTITATIVE AND QUALITATIVE MEASURES OF ARTIFICIAL LIGHTING

Findings pertinent to general ambient illuminance and illuminance at three selected work areas under artificial lighting are projected along with estimated values for illuminance uniformity. Subjective assessment of the qualitative aspects of artificial lighting in terms of shadow and glare is also presented.

6.1 Illuminance under Artificial Lighting

The general ambient illuminance and illuminance at selected task areas under artificial lighting in the kitchen were measured by following a standard procedure with the aid of a photometer. While the general ambient illuminance under artificial lighting (IuAL) was measured on the horizontal boundary surface at selected points across the room at a height of 81 cm above the floor, the illuminances at task areas were measured on the kitchen platform. No specific area was ear-marked as a particular work center in the kitchens surveyed. Hence, three work areas, namely, cooking area, pre-preparation area and sink area were identified by the investigator on the basis of housewife's responses on the use of platform space for performing various kitchen – related activities and measurement of illuminance was carried out at each of the work areas. It is to be noted that the measurements were taken without the worker at the respective work areas, thus avoiding the scope of any shadow being cast on the work surface. This was done so as to assess the maximum illuminance available at the different selected points under existing artificial lighting conditions.

Table 27 : Distribution of kitchens by general ambient illuminance and illuminance at selected task areas through artificial source of light

Illuminance (lx)	General		Cooking area		Pre - preparation area		Sink area	
	N	%	N	%	N	%	N	%
25 or less	8	3.8	48	23.1	45	21.6	62	29.8
25.1-50.0	80	38.5	87	41.8	87	41.8	66	31.7
50.1-75.0	83	39.9	34	16.3	44	21.2	42	20.2
75.1-100.0	30	14.4	19	9.1	15	7.2	24	11.5
100.1-125.0	6	2.9	8	3.8	13	6.3	7	3.4
125.1-150.0	1	0.5	5	2.4	3	1.4	5	2.4
150.1-175.0	-	-	4	1.9	1	0.5	1	0.5
175.1-200.0	-	-	2	1.0	-	-	1	0.5
200.1 & more	-	-	1	0.5	-	-	-	-
Total	208	100	208	100	208	100	208	100
Median	54.00		42.40		39.70		39.50	
Mean	55.89		50.63		47.16		47.66	
S. D.	21.07		36.49		29.42		32.82	

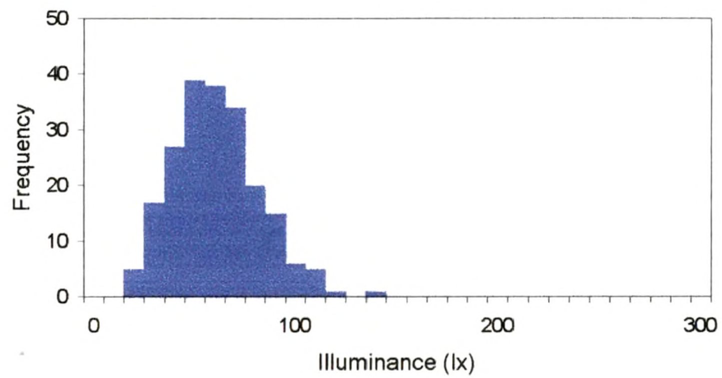


Figure 1: Average general ambient illuminance under artificial lighting (mean = 55.89 lx)

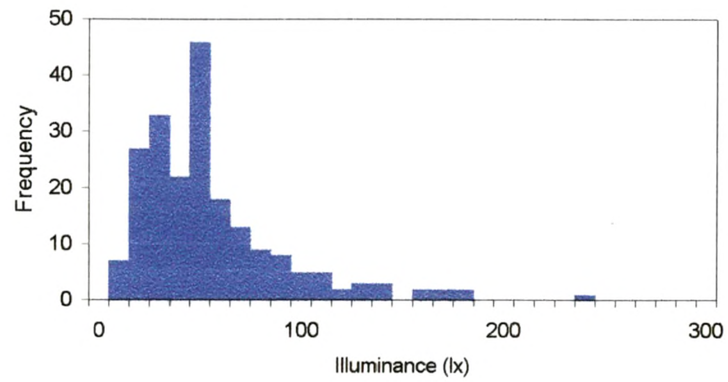


Figure 2: Average illuminance at cooking area under artificial lighting (mean = 50.63 lx)

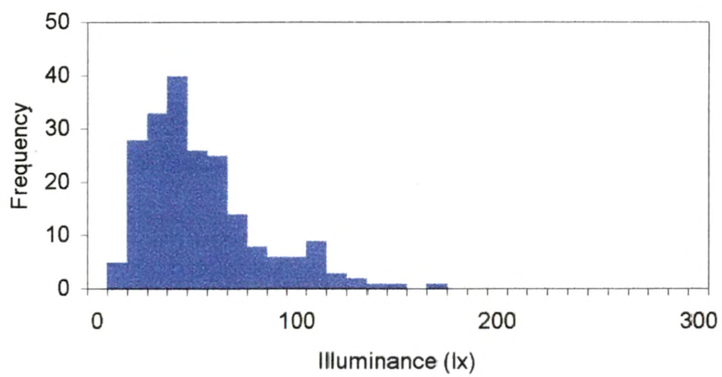


Figure 3: Average illuminance at pre-preparation area under artificial lighting (mean = 47.16 lx)

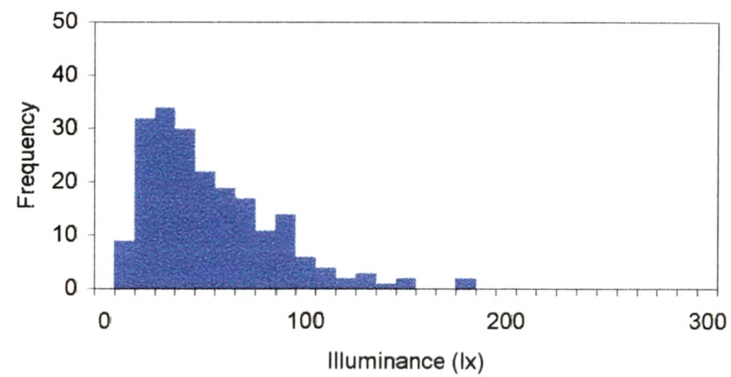


Figure 4: Average illuminance at sink area under artificial lighting (mean = 47.66 lx)

The general ambient IuAL in the kitchens ranged between 10.3 lx to 139.3 lx with a mean of 55.89 lx. In more than three-fourth of the kitchens, the general ambient IuAL was between 25.1 lx to 75.0 lx (Fig. 1). The mean value of average illuminance on the total kitchen platform was found to be 48.7 lx, while the means of the illuminance at the cooking area, pre-preparation area and sink area were found to be 50.63 lx, 47.16 lx and 47.66 lx respectively and the range of illuminance at the three task areas fell between 3.5 lx to 230.3 lx. In one of the kitchens the average IuAL at the sink was even zero (Fig. 2, 3 & 4). The distribution of data on the basis of mean and S.D. revealed that more than two-third of the kitchens belonged to the moderate category of illuminance lying between 34.82 and 77.00 lx (Table 18, Appendix V). The existing illuminances thus, were assessed to be extremely poor as compared to the standard values.

The recommended illuminances as per International Standards (Philips Lighting Manual, 1993) for general and task lighting in kitchen are 300 lx and 500 lx respectively. In the present investigation general ambient IuAL and illuminance at the task areas were one-fifth and one-tenth respectively as that of the standard values. The existing illuminances under artificial lighting were found to be approximately one-fourth of recommended value of 200 lx (I.S.I., 1966). The findings of the present study in relation to the existing illuminances agrees well with those of Desai (1977), Saxena, Kumar and Pal , (1980), Merz (1982) and Luthra (1987). In other words, lighting in the kitchen remained more or less the same over a span of two decades.

6.2 Illuminance Uniformity (IU)

To express the uniformity of illuminance in the space under investigation, the ratio of the minimum to the average ambient illuminance was computed in the case of each field kitchen. The IU for the entire room ranged from 0.02 to 0.77 and the mean was found to be 0.33, while the IU for the platform area and the area surrounding the platform (i.e., entire room area – platform area) ranged between 0.01 to 0.86 and 0.01 to 0.80 with mean value of 0.43 and 0.36 respectively.

Table 28 : Frequency and percentage distribution of kitchens by illuminance uniformity

Range in Illuminance uniformity (IU)	IU for entire room		IU for platform area		IU for area surrounding the platform*	
	N	%	N	%	N	%
0.10 or less	17	8.17	10	4.81	15	7.69
0.11-0.20	31	14.90	17	8.17	25	12.01
0.21-0.30	43	20.67	31	14.90	41	19.71
0.31-0.40	52	25.00	35	16.43	42	20.19
0.41-0.50	34	16.35	38	18.27	36	17.31
0.51-0.60	17	8.17	32	15.34	22	10.58
0.61-0.70	10	4.81	23	11.06	18	8.65
0.71 or more	4	1.92	22	10.58	8	3.85
Total	208	100.00	208	100.00	208	100.00
Mean	0.33		0.43		0.36	
S.D.	0.16		0.20		0.18	

* the entire room – platform area is identified as the area surrounding the platform

With regard to the IU for the entire room and for the area surrounding the platform, IU ranged between 0.21 to 0.50 in about 60 per cent of the kitchens while in similar proportion of the kitchens the IU for the platform area ranged between 0.31 to 0.70. The IU was estimated to be more than 0.50 for platform area in one-third of the kitchens and for the area surrounding the platform in one-fourth of the kitchens, while the IU for the entire room was more than 0.50 in only one-tenth of the kitchens. The findings revealed that the distribution of light on the platform area was relatively more uniform as compared to that in the entire room even though it was deficient. With regard to the categorisation of kitchens by mean and S.D., it was found that more or less equal proportion of kitchens exhibited > 0.17 (high) and < 0.49 (low) IU and the majority were grouped in the moderate category of IU to (0.17 to 0.49) (Table 17, Appendix V).

The values pertaining to IU revealed extreme contrasts in illuminance at different points of measurements in the kitchens. This can be explained by the very fact that 97 per cent of the kitchens had a single source of light which in majority of the cases was mounted on any one of the walls of the kitchen without any planning. With such lighting installation, the distribution of light across the kitchen would be uneven with some portion of the room being better lit with some areas poorly lit, the former being not necessarily the work area. As per the standard recommendations, the illuminance uniformity should normally be not less than 0.8 in case of general lighting (IES, 1973 and Philips lighting Manual, 1993). The value of 0.8 is recommended in order to provide for equivalent task locations throughout the interior. IU holds relevance along the work areas of platforms in case of kitchens having one wall or corridor or L-shape or U-shape layout, where the specific task areas are located along the walls. However, this value for the entire room would be appropriate for island or peninsula types of kitchens and also for such kitchens where the worker might pursue any pre-preparation task in any part of the kitchen other than the work area along the platform.

The ratio of average illuminance at specific task areas to the average illuminance in the surrounding area was also estimated. In the case of localised (general) lighting or a combination of general and local lighting, the illuminance at the task areas should normally be three times that of the average illuminance in the areas surrounding the tasks (Philips lighting Manual, 1993). In other words, the ratio of illuminance task at to that in the surrounding area should ideally be 3:1. The data in the present investigation revealed that the ratio of illuminance at task and the surrounding area was far below the recommendations. In approximately 70 per cent of the kitchens the ratio was found to be less than 1.00, indicating the fact that in these kitchens the illuminance at the three work areas was less than the average illuminance in the surrounding area which could be attributed to the location of lamps. The mean ratio between the illuminance at the cooking area, pre-preparation area and sink area to that in the surrounding area was 0.9, 0.8 and 0.9 respectively. In about 15 to 20 per cent of the kitchens the illuminance ratio was between 1.00 to 1.50 suggesting that the illuminance at the task area was either equal to or one and a half times more than the area surrounding the task area (Table 29).

The poor illuminance ratio observed between the task area and surrounding area in the kitchens were the consequences of inappropriate lighting system that included a single source of light located away from work areas providing localised general lighting. On the other hand, a combination of general lighting and local lighting with adequate and appropriately positioned lamps would be the ideal lighting method to meet the recommended values.

Table 29 : Distribution of families by illuminance ratio between task and area surrounding the task

Illuminance ratio (Task/Area surrounding the task)	Cooking		Pre - preparation		Sink	
	N	%	N	%	N	%
Less than 1.0	147	70.67	149	71.63	140	67.31
1.00-1.50	34	16.35	45	21.63	42	20.19
1.51-2.00	21	10.10	10	4.81	19	9.13
2.01-2.50	4	1.92	2	0.96	5	2.40
2.51-3.00	1	0.48	2	0.96	1	0.48
3.01 or more	1	0.48	-	-	1	0.48
Total	208	100	208	100	208	100
Mean	0.9		0.8		0.9	
S. D.	0.50		0.43		0.53	
Minimum	0.12		0.11		0.00	
Maximum	3.63		2.78		3.97	

6.3 Glare

The degree of glare experienced is a function of the luminances in the visual field and is an important criteria to assess the quality of a visual environment. The International Commission on Illumination (CIE) has classified tasks and activities into quality classes according to the degree of luminance control needed. The kitchen tasks are identified as B-C quality class i.e., high quality – moderate quality class. These are tasks with high visual demands or with moderate visual demands calling for high concentration or with moderate visual demands and moderate demands on concentration and with a certain degree of mobility of the worker with corresponding glare rating being 1.50-1.85 (Phil ips Lighting Manual, 1993).

Table 30 : Distribution of kitchens by degree of glare at the work areas

Degree of glare	N	%
Unnoticeable	49	23.56
Noticeable	126	60.58
Just admissible	27	12.98
Disturbing	6	2.88
Unbearable	-	-
Total	208	100.00

In the present study, a subjective assessment of degree of glare was carried out at the work areas in each of the kitchen, using a scale on which principal points were marked as shown in Table 30. It was found that majority of the kitchens (60 per cent) were marked as having 'noticeable' degree of glare while in a little less than one-fourth of the kitchen glare was 'unnoticeable' at the work areas. A negligible proportion of kitchens were found with degree of glare that was 'disturbing'. In the kitchens surveyed the quantity of light itself was so low that chances of glare due to excess of light as such were minimum. However, the fact that the lamps were not housed in luminaires was one of the causes of glare in most of the kitchens while in a few kitchens it was found that the light struck directly on the steel utensils stored in open racks that caused annoying glare.

6.4 Shadow

The intensity and extent of shadow formed, when the worker is positioned at the work area, affects the amount of light available at the work area. In practice the worker performs the work under shadowed illuminances and not under potential illuminances. The intensity and extent of shadow would depend on the shadow caster and light source, the latter referring to direction and suspension of the source of light with regard to the work areas and the type of light source i.e., whether a point (disk) source or an extended (line) source. With reference to the 208 kitchens surveyed, it can be theoritically analysed from the position of the lamps in relation to the three work areas that in one-fourth of the kitchens the light source was positioned at the right-hand side of the worker such that the shadow of the right-hand would mask details of the task at hand. In a little less than one-fifth of the kitchens the incident light rays were obstructed by the worker as the source of light was installed behind the worker when working at the three respective work areas, whereby the shadow would fall on the critical area of the place just in front of the worker. In less than one-half of the kitchens, the light struck the three work areas either from the front or from the left-hand side of the worker. The latter light directions are considered as the ideal and thus are recommended for distracting shadows.

Further, it was found that 87.5 per cent and 7.2 per cent of the kitchens had bare fluorescent lamp and incandescent lamp respectively as the only source of light. A characteristic effect of a point source of light (incandescent bulb) if obstructed by the shadow caster, is the production of full shadow or umbra while that of an extended light source (fluorescent tube) is the formation of semi shadow or pen umbra. However, to achieve optimal conditions of quality light, fully extended light source represented by a luminous hemisphere of uniform brightness is recommended. Such an arrangement would result in illuminance being practically free from shadow or "perfectly diffused" (Norden, 1948).

Also a subjective judgement of intensity of shadow, when the worker was positioned at each of the three work areas, was carried out. It was found that about 70 per cent of the kitchens were characterised by soft or medium shadow at cooking and pre-preparation area and similar observation was true in case of the sink area in a little more than 60 per cent of the kitchens. In about one-fifth of the kitchens, the sink area was characterised by a sharp shadow (Table 31).

Table 31 : Distribution of kitchens by the characteristic of shadow at the work areas

Shadow	Cooking area		Pre-preparation area		Sink area	
	N	%	N	%	N	%
Nil	36	17.31	35	16.83	34	16.35
Soft	73	35.10	89	42.79	75	36.06
Medium	72	34.62	57	27.40	58	27.88
Sharp	27	12.98	27	12.98	41	19.71
Total	208	100.00	208	100.00	208	100.00

7. DAYLIGHTING IN KITCHENS

Observations pertinent to daylighting in a subsample of 148 kitchens are presented. Findings with respect to area of aperture, aperture-floor ratio, orientation of kitchen, daylight factor, general illuminance and illuminance at work areas and uniformity ratio are discussed.

7.1 Area Of Aperture

Windows and doors are the primary areas for penetration of natural light. Besides admitting light, they fulfil essential visual functions by allowing a view of the outside. It is also believed that they have an influence on health and general well being especially in a domestic environment.

The area of aperture in the selected kitchens was estimated as the total area of doors and windows present on the exterior wall(s) of the kitchens. The range in the area of aperture in the kitchens was 0.32 to 8.87. The mean area of aperture was estimated to be 2.27. In more than one-third of the kitchens the area of aperture ranged between 2.01 to 2.50, while in nearly one-fourth of them, the area of aperture was more than 2.76 (Table 32). Analysis of data revealed that approximately three-fourth of the kitchens belonged to the medium category by area of aperture the same falling between 1.19 and 3.35 while a small proportion of kitchens comprised of either of the extreme categories (Table 18, Appendix V). In general, it was observed that about one-half of the kitchens had one door and one window along the exterior wall(s) of the kitchen.

Table 32 : Distribution of kitchens by area of aperture in exterior wall(s)

Area of aperture (m^2)	N	%
0.26 – 0.50	4	2.7
0.51 – 0.75	6	4.1
0.76 – 1.00	8	5.4
1.01 – 1.25	4	2.7
1.26 – 1.50	8	5.4
1.51 – 1.75	9	6.1
1.76 – 2.00	11	7.4
2.01 – 2.25	24	16.2
2.26 – 2.50	31	20.9
2.51 – 2.75	10	6.8
2.76 or more	33	22.3
Total	148	100.00
Mean	2.27	
S.D.	1.08	

7.2 Aperture-Floor Ratio

The aperture-floor ratio in the present study refers to the ratio of area of aperture in exterior wall(s) to the floor area of the kitchen. It is an important indicator that suggests the appropriateness of size of aperture, i.e. doors and windows in a given room. Peet, Picket and Arnold (1975) and Grandjean (1988) recommended that the window area for workrooms should be about one-fourth or one-fifth of the floor area.

The aperture-floor ratio in the selected kitchens ranged between 0.03 to 0.89 implying that at one extreme the aperture area was $1/30^{th}$ (3 per cent) of the floor area while at the other extreme the aperture area was more than $4/5^{th}$ (89 per cent) of the floor area. The mean value for aperture-floor ratio was estimated as 0.26. In more or less similar proportion of kitchens (approximately 30 per cent each) the aperture-floor ratio ranged between 0.11 to 0.20 and 0.26 to 0.35 respectively. In a negligible proportion of kitchens, the aperture-floor ratio was observed to be more than 0.51. The categorisation of kitchen based on mean and S.D. revealed that a little less than three-fourth of the kitchens belonged to the medium category by aperture-floor ratio with the ratios falling between 0.13 and 0.39 while relatively small proportions were identified in low and high categories (Table 19, Appendix V).

Table 33 : Distribution of kitchens by aperture – floor ratio

Aperture – floor ratio	N	%
0.10 or less	10	6.76
0.11 – 0.15	21	14.2
0.16 – 0.20	22	14.9
0.21 – 0.25	18	12.2
0.26 – 0.30	24	16.2
0.31 – 0.35	23	15.5
0.36 – 0.40	15	10.1
0.41 – 0.45	7	4.7
0.46 – 0.50	2	1.4
0.51 – or more	6	4.05
Total	148	100.00
Mean	0.26	
S.D.	0.13	

7.3 Orientation of Kitchen

Orientation of room space is considered as a crucial aspect in the overall plan of design. Deshpande (1985) suggested an east or north-east orientation for kitchens. Since the opening facing east admits strong sunlight early in the morning purifying the air, and loses the sun in the afternoon, thus keeping the room cool during the other part of the day. Opening facing north which never admit direct sun, generally receive cool and consistent light. A north-east orientation would have the advantage of direct sunlight in the morning as well as cool consistent light throughout the day. Although south orientation has the advantage of receiving sun consistently for most of the day, due to excess of radiant heat, this orientation is generally not recommended for a kitchen which itself is a warm place. West facing opening receive late afternoon sun sometimes, too much sun on summer afternoon. Thus based on orientation for a kitchen suggested by Deshpande, three categories of orientation were identified for the present study. The orientation of kitchens having all the apertures towards either north or north-east side was identified as desirable. In case of kitchens having two or more exterior walls and atleast one of them facing either north or north-east side, their orientation was categorised as neutral (combination of desirable and undesirable orientation) while the orientation of kitchens towards directions other then these two were referred to as undesirable. More than three-fourth of the selected kitchens were observed to have an undesirable orientation of exterior walls and less the one-fifth had a neutral orientation. It was found that only 15 per cent of kitchens were qualified as having a desirable orientation (Table 34).

Table 34 : Distribution of kitchens by their orientation

Orientation	N	%
Undesirable	97	65.54
Neutral	28	18.92
Desirable	23	15.54
Total	148	100.00

A little less than one-third of the kitchens had at least one exterior wall towards either south or south-east side while a little more than one-third had at least one exterior wall facing the north (Table 20, Appendix V). The former orientation was favourable in terms of the amount of daylight pouring into the kitchen. However, many housewives reported about problems related to glare due to excessive lights in the kitchen, especially in the kitchens where steel utensils were stored in open racks. Also it was reported that the direct sun rays striking on the steel burner created problems during the cooking time. Many families thus had created obstructions on the window or had kept the window sealed to block the entry of light into the kitchen and used artificial light during day time.

It appeared that not much thought and attention were given on the impact of orientation while planning the kitchens. In spite of many kitchens having large apertures, the day light was not exploited quantitatively and qualitatively to its maximum advantage.

7.4 Distribution of Kitchens by Average Day Light Factor

The day light factor (DLF) was computed for each of the selected kitchen as the ratio of average general ambient IuNL in the kitchen to the out door illuminance under unobstructed sky. The average day light factor recommended for kitchens by the Bureau of Indian Standards (ISI, 1975) is 2.50 per cent and that recommended by British Standard Institution (BSI, 1992) is 2.00 per cent. The range in average day light factor in the selected kitchens was observed to be between 0.02 per cent and 37.70 with a mean DLF of 2.27 per cent and an S.D. of 4.41. A little less tan one-half of the kitchens had less than or equal to 0.50 while one-third of them had more than 2 per cent an average day light factor (Table 35).

Table 35 : Distribution of kitchens by average day light factor

Day light factor (%)	N	%
0.10 or less	17	11.49
0.11 – 0.50	53	35.81
0.51 – 1.00	9	6.08
1.11 – 1.50	13	8.78
1.51 – 2.00	8	5.41
2.11 – 2.50	13	8.78
2.51 – 3.00	6	4.05
3.11 – 5.00	10	6.76
5.11 – 7.00	9	6.08
7.11 – 9.00	3	2.03
10.00 or more	7	4.73
Total	148	100.00
Mean	2.27	
S.D.	4.41	

7.5 Illuminance under Natural Lighting

The general ambient illuminance and illuminance at selected task areas under natural lighting in the kitchen were measured using a photometer following a similar procedure as used for the measurement of artificial illuminance. A wide range in the general ambient illuminance under natural lighting (2.78 lx to 2275.91 lx) was observed across the kitchens with a mean value of 203.32 lx and S.D. of 220.80 (Fig. 5). Such extreme variations were also observed with regard to illuminances at the cooking area, pre-preparation area and sink area, where the mean illuminances were estimated to be 192.29 lx, 162.14 lx and 152.93 lx. In less than one-third of the kitchens each, general ambient iluminance was observed to be less than or equal to 100 lx and more than 250 lx respectively (Fig. 6, 7 and 8).

With regard to the illuminances at the task areas it was found that about one-half of the kitchens had illuminances less than or equal to 100 lx while 22 per cent and 16 per cent each of kitchens had illuminaces more than 250 lx at the cooking area, pre-preparation area and sink area respectively (Table 36).

The categorisation of kitchens by mean $\pm$ S.D. indicated that about 90 per cent of kitchens belonged to moderate category while a small proportion constituted the high category (Table 23, Appendix V). The higher levels illuminances can be accounted for by higher aperture-floor ratio and/or increased height of windows above working plane and/or east or south or south-east orientation and/or minimum exterior obstructions to the aperture from neighbouring buildings and trees. On the contrary, the lower levels of illuminances can be explained by lower aperture-floor ratio and/or

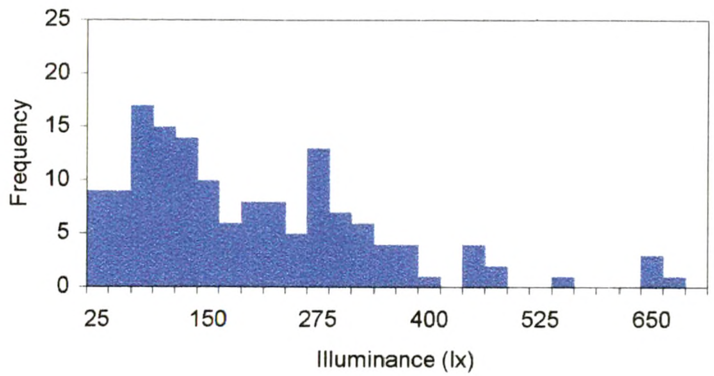


Figure 5: Average general ambient illuminance under daylighting (mean = 203.32 lx)

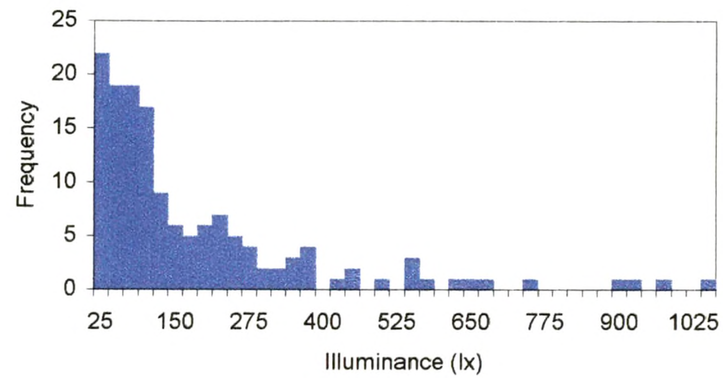


Figure 6: Average illuminance at cooking area under daylighting (mean = 192.29 lx)

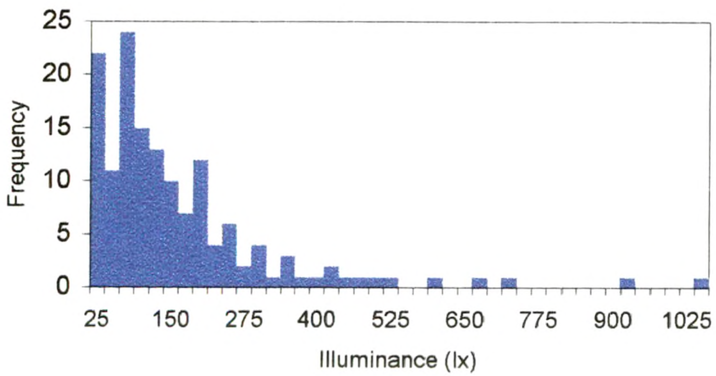


Figure 7: Average illuminance at pre-preparation area under daylighting (mean = 162.14 lx)

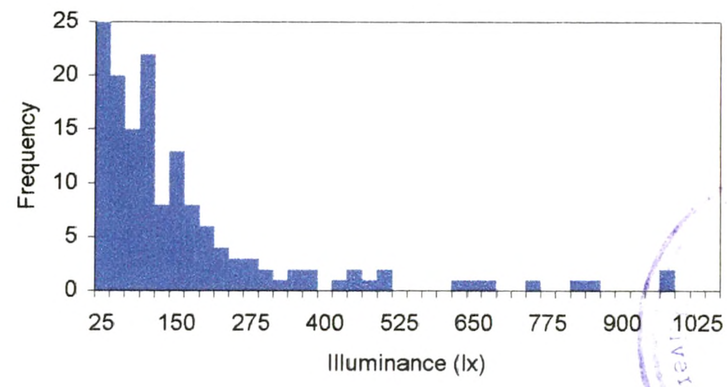


Figure 8: Average illuminance at sink area under daylighting (mean = 152.93 lx)

lower height of windows above the working plane and/or north or west orientation and/or heavy obstructions to the aperture from neighbouring buildings and trees.

Table 36 : Distribution of kitchens by average general ambient illuminance and average illuminance at selected task areas under natural lighting

	Average Illuminance							
Illuminance (lx)	Ambient general		cooking area		pre-preparation area		sink area	
	N	%	N	%	N	%	N	%
50 or less	17	11.5	42	28.4	32	21.6	46	31.1
51 - 100	32	21.6	35	23.6	40	27.0	36	24.3
101 - 150	24	16.2	15	10.1	23	15.5	21	14.2
151 - 200	13	8.8	11	7.4	19	12.8	14	9.5
201 - 250	15	10.1	12	8.1	10	6.8	7	4.7
251 or more	47	31.8	33	22.3	24	16.2	24	16.2
Total	148	100.00	148	100.00	148	100.00	148	100.00
Mean	203.32		192.29		162.14		152.93	
SD	220.80		263.48		201.73		187.97	

7.6 Illuminance Uniformity (IU)

The illuminance uniformity in each of the selected kitchens was expressed in terms of the ratio of the minimum to the average illuminance. The observed range in the IU was between 0.10 to 0.76 with the mean of 0.14. In about two-third of the kitchens, the IU ranged between 0.11 to 0.40 (Table 37). Analysis of data in terms of mean and S.D. revealed that more than two-third of the kitchens were categorised in the moderate group while equal number of kitchens were in the two extreme groups (Table 24, Appendix V). However, as per the recommendations the existing IU were assessed to be very low. The low IU could be explained by the fact that the penetration of daylight through doors and windows was from one direction which lead to higher concentration of light in one part of kitchen while the other part remained dark.

According to Galer (1987), an important aspect in the design of day lighting is to distribute light evenly over a large working area. This is only possible if the light comes from sky lights rather than from side windows, though the latter are desirable to provide visual relaxation and contact with the outside.

Table 37 : Distribution of kitchens by illuminance uniformity under natural lighting

Illuminance uniformity	N	%
0.10 or less	9	6.08
0.11-0.20	26	17.57
0.21-0.30	32	21.62
0.31-0.40	42	28.38
0.41-0.50	21	14.19
0.51-0.60	15	10.14
0.61 or more	3	2.23
0.71-0.80		
Total	148	100.00
Mean	0.31	
S.D.	0.14	

8.0 PROFILE OF RESPONDENTS HAVING KITCHENS WITH HIGH AND LOW AVERAGE AMBIENT GENERAL ILLUMINANCES

Data from 27 per cent of respondents each having kitchens with high and low average ambient general illuminances respectively were examined to have an understanding about their salient characteristics. The profile of respondents of kitchens with high and low IuAL is dealt with first and then the profile of kitchens with high and low IuAL are presented.

8.1 Profile of Respondents having Kitchens with High and Low IuAL

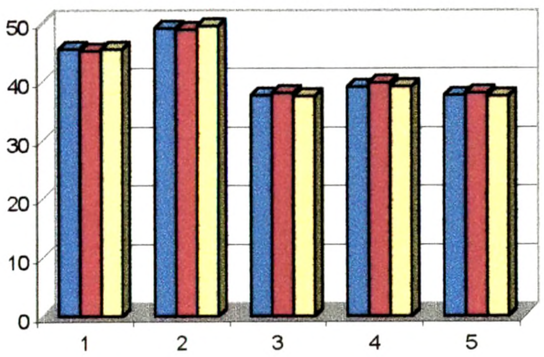
Data from 56 respondents each having kitchens with high and low IuAL respectively were scrutinised with regard to their family, personal and situational characteristics. The families having kitchens with high IuAL in contrast to those having kitchens with low IuAL were characterised by relatively higher family income, lower age of the house and there were more number of these families residing in owned houses (Table 38 and Fig. 10). The kitchens with high IuAL were distinguished with relatively smaller floor area, lower mounting height of lamps, higher wattage rating and burning hours of lamps, higher ρ_{CC}, ρ_{FC}, MF and UF, higher levels of illuminaces at work areas, higher illuminance uniformity and higher ratio of illuminance at work areas to surrounding areas (Table 39 and Fig. 10).

On the other hand, those families havings kitchens with low IuAL, in comparison to those having kitchens with high IuAL, were characterised by relatively lower family income, higher age of the house and there were more number of these families residing in rented houses. The kitchens of these families were characterised by relatively larger floor area, higher mounting height of lamps, lower p_{CC}, p_{FC}, MF and UF, lower average illuminaces at work area, lower illuminance uniformity and lower ratio of illuminances at work areas to surrounding areas.

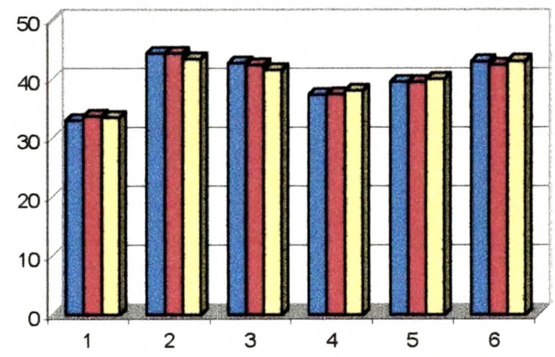
However, the families having kitchens with high and low IuAL compared well regarding mean age of homemaker and husband, scores on each of the six selected values, knowledge level of homemaker and husband and the expanded from perceived level of visual discomfort (PLoD) (Table 38, Fig. 9). The kitchens with high and low IuAL were comparable in terms of room index. The most remarkable contrast in the selected characteristics of kitchens with high IuAL were family income, age of house, tenure of housing, floor area of kitchen, p_{CC}, p_{FC}, MF and UF. The families with higher incomes and those residing in owned accomodation appeared to be more conscious regarding the upkeep of their kitchens. These families probably had choosen appropriate colours and finishes for the room surfaces and they might have invested more in the maintenance of these surfaces, which contributed to higher reflectance and higher UF, and thereby higher levels of illuminance in the kitchen.

Table 38 : Comparison of mean of family and personal characteristics in relation to IuAL

Characteristics		Mean		
		Total sample N=191	High IuAL N=51	Low IuAL N=51
IuAL		55.9	82.9	31.9
		(N=208)	(N=56)	(N=56)
Age of homemaker (years)		45.5	45.2	45.5
Age of husband (years)		49.0	48.8	49.4
		(N=184)	(N=49)	(N=49)
Family income (Rs.)		14426	15527	14884
		(N=172)	(N=46)	(N=48)
Value :	Aesthetic	33.0	33.8	33.6
	Comfort	44.4	44.4	43.5
	Economy	42.7	42.4	41.6
	Modernism	37.4	37.5	38.1
	Safety	39.5	39.5	40.1
	Work efficiency	43.0	42.4	43.1
Knowledge level of homemaker		37.6	38.0	37.5
Knowledge level of husband		39.1	39.8	39.2
		(N=184)	(N=49)	(N=49)
Perceived level of discomfort (PLoD)		37.6	38.0	37.5
Age of house (years)		12.7	9.4	14.0
		(N=181)	(N=51)	(N=45)
Tenure of housing :				
	Owned houses	N=175	N=50	N=42
	Rented houses	N=16	N=1	N=9



1. Age of homemaker 2. Age of husband
3. Know. of homemaker 4. Know. of husband
5. Perceived level of homemaker



Values: 1. Aesthetics 2. Comfort
3. Economy 4. Modernism
5. Safety 6. Work-efficiency

Total sample
High scorers
Low scorers

Figure 9: Mean of personal characteristics of homemakers and husbands in relation to IuAL

Table 39 : Comparison of mean of salient characteristics of the kitchen in relation to IuAL

Characteristics	Mean		
	Total sample N=208	High IuAL N=56	Low IuAL N=56
IuAL	55.9	82.9	31.9
Floor area of kitchen (sq.mt.)	9.13	8.34	9.59
Mounting height of lamps (mt.)	1.60	1.56	1.62
Lamp wattage	40.1	39.7	39.1
Burning hours of lamp	3.3	3.3	2.9
Room index (K)	.983	.994	.994
Effective ceiling cavity reflectance (ρ_{CC})	54.1	56.4	53.0
Effective floor cavity reflectance (ρ_{FC})	30.2	32.3	29.1
Maintenance factor (MF)	.839	.856	.844
	(N=206)	(N=56)	(N=54)
Utilisation factor (UF)	.227	.275	.197
Average illuminance at cooking area	50.6	79.6	28.1
Average illuminance of pre-preparation area	47.2	70.9	27.9
Average illuminance at sink area	47.7	73.8	25.9
Illuminance uniformity for entire room	.331	.314	.386
Ratio of illuminance at cooking area to surrounding area	.890	.945	.885
Ratio of illuminance at pre-preparation area to surrounding area	.843	.848	.866
Ratio of illuminance at sink area to surrounding area	.860	.902	.858

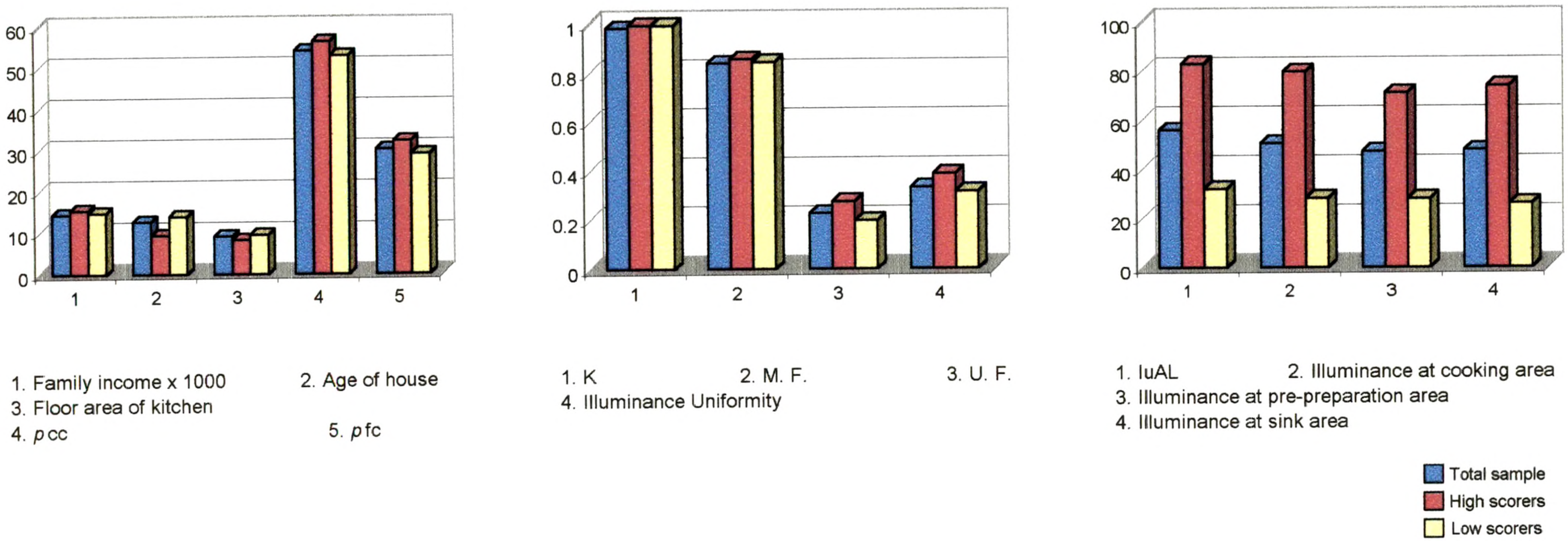


Figure 10: Mean of family and situational and characteristics in relation to IuAL

8.2 Profile of Respondents having Kitchens with High and Low IuNL

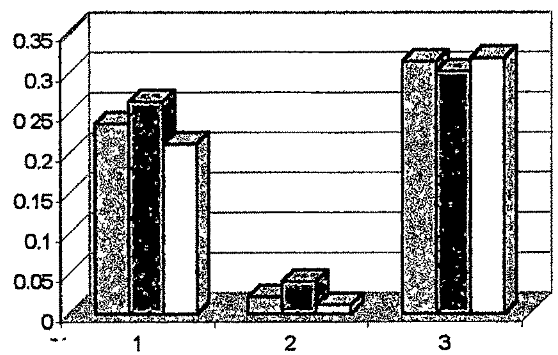
The mean situational characteristics of 40 respondents each having kitchens with high and low IuNL respectively were examined in relation to IuNL. The houses of respondents having kitchens with high IuNL were relatively new as compared to the houses of respondents having kitchens with low IuNL. In contrast to the kitchens with low IuNL, the kitchens with high IuNL had larger floor area, larger area of aperture in exterior wall(s), higher aperture-floor ratio higher average daylight factor, higher average illuminance at work areas but lower illuminance uniformity. Relatively fewer kitchens having high IuNL had undesirable orientation of exterior wall(s) and more had neutral orientation as compared to the kitchens with low IuNL.

On the contrary, the houses of respondents having kitchens with low IuNL were relatively old as compared to those with high IuNL. The kitchens with low IuNL were characterised by relatively smaller floor area, smaller area of aperture in exterior wall(s), lower aperture-floor ratio, lower average daylight factor, lower average illuminance of work areas and higher illuminance uniformity . In contrast to the kitchens with high IuNL, more number of kitchens with low IuNL had undesirable orientation of exterior wall(s) and less had neutral orientation.

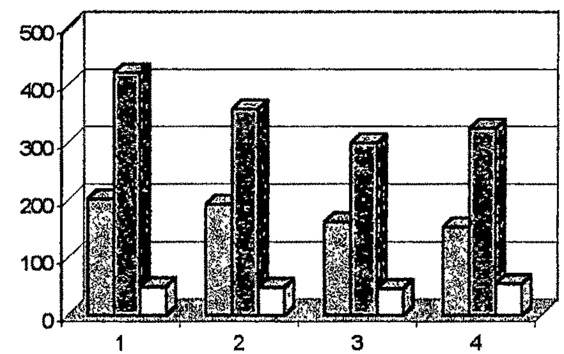
Similar number of kitchens with high and low IuNL had desirable orientation of exterior wall(s) (Table 40). It seemed that the kitchens of relatively newer houses had larger area of aperture in exterior wall(s), larger aperture - floor ratio and probably had relatively better orientation of exterior wall(s) which contributed to entry of more natural light into the kitchen.

Table 40 : Comparison of mean of salient characteristics of the kitchen in relation to average general ambient IuNL

	Mean		
Characteristics	Total sample N=148	High IuNL N=40	Low IuNL N=40
Average general ambient IuAL	201.9	421.3	49.7
Age of house	13.0	8.4	14.0
Tenure of housing			
Owned houses	N=129	N=34	N=34
Rented houses	N=8	N=2	N=3
Floor area of kitchen	9.25	9.86	9.18
Area of window(s) in exterior wall(s)	1.1	1.3	1.0
Area of door(s) in exterior wall(s)	.9	1.2	.8
Total area of apertures (window(s)+door(s)) in exterior wall(s)	2.1	2.4	1.8
Aperture floor ratio	.237	.264	.212
Orientation of exterior wall(s)			
Desirable	N=23	N=6	N=6
Neutral	N=28	N=12	N=5
Undesirable	N=97	N=22	N=29
Average daylight factor	.021	.040	.011
Average IuNL at cooking area	192.6	358.5	48.8
Average IuNL at pre-preparation area	161.5	299.0	46.2
Average IuNL at sink area	153.4	324.8	54.7
Illuminance uniformity	.314	.302	.319



1. Aperture - floor ratio 2. DLF
3. Illuminance Uniformity



1. IuNL 2. Illuminance at cooking area
3. Illuminance at pre-preparation area
4. Illuminance at sink area

Total sample
High scorers
Low scorers

Figure 11: Mean of situational characteristics in relation to IuNL

9.0 HYPOTHESES TESTING

To test the hypotheses statistically, null hypotheses were formulated. Correlation coefficients were computed for variables using the survey data on the entire sample. Product moment correlations and analysis of variance were also computed for illuminance under artificial lighting and the respective thirteen variables. Wherever significant F value was found, t-test was applied. To assess the association between tenure of housing and I_UAL, Chi-square values were computed using Yate's correction. In addition 't' test was applied to ascertain the significance in the mean differences of IuAL by tenure of housing. Questions like where there differences in existing average general ambient illuminances the residential kitchens under artificial lighting and could the differences in the existing illuminances under artificial lighting (IuAL) be accounted by situational variables like age of house, tenure of housing, floor area of kitchen, room index (K), effective ceiling cavity reflectance (p_{CC}), effective floor cavity reflectance(p_{FC}), maintenance factors (MF) and utilisation factor (UF); and was there any relationship between IuAL and personal characteristics like knowledge level of housewives and husbands, values held by housewives and perceived level of discomfort; and family characteristics like the family income formed the basis of analysis of the data gathered through the survey in the present study.

In this section, the observations made in relation to testing of hypotheses are presented. The findings and discussions pertinent to hypothesis A I and A II are summarised:

9.1 Findings and Discussions in Relation to Hypothesis A

For the purpose of testing the hypothesis formulated, null hypothesis was framed. Hypothesis AI states that there exists a relationship between level of average general ambient illuminance under artificial lighting (IuAL) in residential kitchens and the selected situational, personal and family variables. Hypothesis A II states that there exists a difference in the order of significance in the association between the selected situational, personal and family variables and IuAL. Null hypotheses (H_OA I and H_OA II) with sub - hypotheses were framed as presented below.

H_0AI : There exists no relationship between level of average general ambient illuminance under artificial lighting in residential kitchens and the selected situational, personal and family variables.

Situational variables :

H_O AI.$_1$	Tenure of housing
H_O AI.$_2$	Age of house
H_O AI.$_3$	Floor area of kitchen
H_O AI.$_4$	Room index (K)
H_O AI.$_5$	Effective ceiling cavity reflectance (ρ_{CC})
H_O AI.$_6$	Effective floor cavity reflectance (ρ_{FC})
H_O AI.$_7$	Maintenance factor (MF)
H_O AI.$_8$	Utilization factor (UF)

Table 41 : Coefficient of correlation for twelve variables and average general ambient IuAL

		2	3	4	5	6	7	8	9	10.1	10.2	10.3	10.4	10.5	10.6
1.	Age of house	.1157	-.0521	-.0299	-.1860*	-.1548*	-.0703	0.0516	.0118	-.0102	.0132	.0001	.0599	-.0394	-.0256
2.	Floor area of kitchen		.2540**	.0617	.2605**	-.0223	.3216**	.0636	-.0420	.1785*	-.0161	-.1679*	.0477	-.0024	-.0624
3.	Room index (K)			-.2791**	.0729	.0394	.1942**	.0326	-.1073	.0612	0.897	-.2528**	.0796	-.0115	.0512
4.	Effective ceiling cavity reflectance (p_{cc})				.2114**	-.0009	.0771	.0624	.0906	-.0741	-.0065	.1152	-.0087	-.0969	.0771
5.	Effective floor cavity reflectance (p_{FC})					.0679	.1567*	.0711	-.0028	-.0739	.0822	-.0167	-.0179	-.0459	.1007
6.	Maintenance factor (MF)/						-.0256	.0572	.0329	.0829	-.0859	-.1299	.0848	-.0066	.0337
7.	Utilisation factors (UF							.0084	-.0804	-.0222	.0018	-.0128	-.0773	.0922	.0363
8.	Knowledge level of homemaker								.5248**	-.1296	.0309	.0152	.0251	-.0060	.0950
9.	Knowledge level of husband									-.1939**	.2277**	-.0164	.0508	-.0844	.0787
10.1	Values : aesthetics										-.3533**	-.3805**	.3338**	-.3849**	-.4544**
10.2	comfort											-.1610*	-.3953**	-.1080	.2332**
10.3	economy												-.2455**	-.0441	-.1885**
10.4	modernism													-.4152**	-.4430**
10.5	safety														.0526
10.6	work efficiency														
11.	Perceived level of discomfort														
12.	Family income														

Personal variables :

H_O AI.$_9$ Knowledge level of housewives

H_O AI.$_{10}$ Knowledge level of husbands

H_O AI.$_{11}$ Values held by housewives with regard to artificial lighting

H_O AI.$_{12}$ Perceived level of discomfort

Family Variable :

H_O AI.$_{13}$ Family income

H_0AII : There exists no difference in the order of significance in the association between the selected situational, personal and family variables and IuAL.

H_O AI.$_1$ There exists no relationship between IuAL and tenure of housing.

It was found that about 92.0 per cent of the families resided in their own house while 8.0 per cent occupied rented accomodation. Chi square was computed to study the association between IuAL in the kitchen and the tenure of housing. A significant association at 0.05 was revealed between the two variables ($\chi^2 = 5.057^*$). The 't' test was also carried out to study the significance in the mean differences between the mean values of IuAL in owned and rented houses. It was found that the IuAL differed significantly at 0.5 level between the owned and rented houses. (Table 42)

Table 42: Difference between mean IuAL by tenure of housing

Group	Tenure of housing	N	Mean IuAL
1	Owned	175	56.64
2	Rented	16	45.41
Mean contrast	**Difference**	**'t' value**	**Level of significance**
1 2	11.23	2.41	.05

The analysis of data clearly indicated that IuAL in the owned houses were higher as compared to that in the rented houses. This observation is in line with that of Desai (1977), and Simpson and Tarrant (1981). The latter investigators reported that ownership of house was linked with greater average wattage rating of the light sources since there were more number of light sources in the kitchens of owned houses. Either fluorescent lamps or CFL were found in 93 per cent of kitchens in owned houses as compared to fluorescent lamps of similar wattage rating in 87 per cent of kitchens in rented houses. The remaining kitchens had incandescent lamps, the wattage rating of the same being higher in case of owned houses.

The well maintained room surfaces and lamps / luminaires might have accounted for relatively higher illuminances in the owned houses. On the other hand, low illuminances in the rented houses could be so because the tenants might not have been wanting to invest on major repair and maintenance of the house which is a temporary place of residence for them and for which they did not have a sense of ownership. Probably the inmates of rented house did not realize its impact on the light loss. Or it could be that the terms and conditions of tenancy did not permit to make alterations as per their preferences and requirements. The IuAL in the kitchens in owned houses was far below the recommended values. In spite of the fact that the house owners had all the freedom and liberty to decide upon what, where and how to install the lighting fixtures, the lighting installation in their houses was inadequate. This could be because of lack of awareness and cognizance about the importance of good lighting.

H_O $AI._2$ There exists no relationship between IuAL and age of House

The mean age of house was 12.71 years (Table 7). Coefficient of correlation between IuAL and age of house were computed using Pearson Product Moment Formula. A negative correlation was found to exist between age of house and IuAL ($r = -.2068^{**}$) (Table 41) implying that as age of house increased the IuAL in kitchens decreased. However, no significant relationship was indicated by the computed 'F' values. Therefore the null hypothesis was partially rejected.

The quality of room surfaces on which the light rays strike has got a bearing on the luminance since the room surfaces are the secondary light sources from where the greatest portion of the luminous flux is reflected. The quality of surface in terms of its reflectance property tends to deteriorate with the age factor unless the surfaces are maintained and kept free of dirt and dust. The floor that is treaded over for many years is likely to loose its reflectance quality if not well maintained. A negative correlation between age of house and ρ_{FC} revealed that reflectance of floor cavity decreased with increase in the age of house which can be identified as one of the factors attributing to low illuminances in old houses. However, no significant relationship existed between age of house and ρ_{CC} which could be because the room cavity, above the plane of luminaires which is normally out of reach for general use, does not undergo the routine wear and tear. Moreover, in 90 per cent of the kitchens the ceiling was given a white wash which might account for a relatively higher reflectance irrespective of the age of the house.

Alternatively, low illuminances in older houses could be owing to low maintenance factor (MF) as well. A negative relationship was observed between age of house and MF indicating that as the age of house increased the MF decreased. Depreciation in light is associated with factors like lamp lumen maintenance, lamp survival and luminaire maintenance (Philips Lighting Manual, 1993). It could be that the effect of depreciation of light was more pronounced in older houses where the period of use of a given lamp(s) might have stretched over a longer span leading to a decrease in luminous output of lamps. Also reduction in lamp efficiency caused by frequent voltage fluctuations or irregular switching cycle or ballast variations or unsuitable luminaire ambient temperature over the years might have contributed to reduction in illuminances in the older houses. Losses in light in older houses could also be accounted for by the accumulation of dust, grease and smoke on the surface of the lamp, especially from the cooking activities, if the cleaning cycle of lamps was irregular and scanty.

Probably, the higher mounting height in older houses, made it difficult to reach the lamps and hence hindering its regular cleaning. On the other hand, the lamps might have been installed at an accessible height in the new houses adding to the convenience of the inmates of the house for their maintenance. Thus it seems that the interplay of p_{FC} and MF with the age of house might be responsible for the low illuminances in older houses.

H_O AI.3 There is no relationship between IuAL and floor area of kitchen

The range in floor area of kitchens was observed to be from 4.20 to 18.24 m^2 with the mean value of 9.13 m^2. Pearson Product Moment correlations revealed a significant negative relationship ($r = - 0.1459^*$) between IuAL and floor area of kitchens (Table 41). The 't' test was applied in order to ascertain the association between IuAL and floor area of kitchen.

Table 43: Difference between mean IuAL by floor area of the kitchen

Group	Area of kitchen	N	Mean IuAL
1	Small	35	66.38
2	Medium	136	54.16
3	Large	37	52.32

Mean Contrast	Difference	't' value	Level of significance
1 2	12.22	3.26	.01
2 3	1.84	0.44	n.s.
1 3	14.06	2.75	.01

There was a progressive increase in mean illuminance in kitchens with increasing ranges in size. Mean IuAL differed significantly at .01 level between kitchens with (i) small and medium as well as (ii) small and large floor areas. The difference in average illuminance between medium and large kitchens was not as pronounced as that between small and medium kitchens (Table 43).

The null hypothesis was rejected.

The differences in mean IuAL by floor area can be interpreted with an inverse mathematical relationship that exists between floor area of a room and lumen per square meter (lx), where the initial lx is expressed as the ratio of the total lamp lumen to the floor area. In practice the lamp lumen is adjusted for the UF and MF (IES, 1966). Table 10, Appendix V reveals that 85 per cent of the kitchens were furnished with a bare 36/40 watt fluorescent lamp providing general lighting and the initial lumen output of such a lamp is approximately computed as 2450 lumens (Philips Lamp Catalogue). The ratio of the estimated lumen to the respective floor areas of small, medium and large kitchens elucidate the differences in illuminances. The mean values for mean IuAL were 66.38 lx, 54.16 lx and 52.32 lx for the small, medium and large sizes of kitchen respectively.

As per the guidelines from American Home Lighting Institute (Butler, 1991), a kitchen requires minimum of ¾ to 1 watt of fluorescent light for every square foot for general purpose. For fluorescent under cabinet lights, use of 8 watts of light for every foot of counter is suggested. However in 99.5 per cent of the kitchens selected for the present study there were no provision for task lights and the wattage distribution per square foot for general lighting was estimated to be 0.58 watt, 0.38 watt and 0.26 watt in the small, medium and large size kitchens respectively.

In general, it was found that the lamp(s) installed in the kitchens were deficient in lumen output with regard to the floor area of the kitchens. The average illuminance was observed to be far below the recommended values due to installation of lamps with low lumen output.

H_O $AI._4$ There exists no relationship between IuAL and room index(K)

The coefficient of correlation computed between K and IuAL was not significant. Thus it was evident that there exists no relationship between IuAL and K (Table 41). The null hypothesis was accepted.

H_O $AI._5$ There exists no relationship between IuAL and effective ceiling cavity reflectance (p_{CC})

To test this hypothesis coefficient of correlation was computed which revealed that there was no significant relationship between IuAL and p_{CC} (Table 41). The null hypothesis was accepted.

H_O $AI._6$ There exists no relationship between IuAL and effective floor cavity reflectance (p_{FC})

The coefficient of corrleation computed between p_{FC} and IuAL was not significant (Table 4). The null hypothesis was accepted.

H_O $AI._7$ There exists no relationship between IuAL and MF

The coefficient of correlation computed between MF and IuAL was not significant (Table 41) The null hypothesis was accepted.

H_O $AI._8$ There exists no relationship between IuAL and UF

The range in utilisation factor (UF) of light emitted from the lamp(s) installed in the residential kitchens was estimated to be 0.04 to 0.91 with a mean value of 0.23. A significant positive correlation (r = 0.318**) was found between UF and IuAL (Table 41.). Significant differences at 0.01 level were observed in mean IuAL when compared by UF. The IuAL in the kitchens with low UF differed significantly (0.01 level) from those with (i) moderate and (ii) high UF. Similarly kitchens belonging to the category of moderate and high UF differed significantly (0.05 level) from each other in their IuAL (Table 44). The null hypothesis was rejected.

Table 44: Difference between mean scores on IuAL by UF

Group	UF	N	Mean IuAL
1	Low	20	37.81
2	Moderate	160	55.88
3	High	26	68.89
Mean contrast	**Difference**	**'t' value**	**Level of significance**
1 2	18.07	6.66	0.01
2 3	13.01	2.42	0.05
1 3	31.08	5.52	0.01

In general, kitchens appeared to have relatively higher illuminances with higher UF and vice versa, which is in line with the natural relationship between the two concepts (IES, 1966). There was progressive increase in the mean IuAL with a shift from low to high category by UF. An analysis of the interplay of the components that constitute the UF might further this finding. The UF by definition is proportion of light emitted by the bare lamp(s) that falls on the working plane and is accounted by (i) room index (K) (ii) reflectance of room surfaces and (iii) absorption of light in the luminaires. A significant positive correlation was found between UF and K and UF and p_{FC} revealing an increase in UF with increase in K and p_{FC}. No significant correlation was observed between UF and p_{CC} implying that p_{CC} might not have contributed significantly to differences in UF in the kitchens. With regards to the absorption of light in the luminaire, the effect could be more or less the same across the kitchens because in more than 98 per cent of the cases the lighting fitting was a bare fluorescent lamp or a bare incandescent lamp where the question of absorption of light by the luminaire was very negligible.

K which reflects the combined effect of room size, room proportions and mounting height of lamp(s), and p_{FC} appear to have attributed to the differences in UF. The observations of the study imply that with an increase in K and p_{FC}, there was an increase in UF with accompanying increase in illuminance.

H_O AI.$_9$ There exists no relationship between IuAL and knowledge level of housewives

The range in scores earned by housewives on the knowledge test regarding artificial lighting was observed to be 27.0 to 47.0 with the mean score of 37.6. The computed 'r' values revealed a positive relationship ($r = 0.1484^*$) between knowledge level of housewives and IuAL suggesting that an increase in knowledge level of housewives was associated with an increase in illuminance in the kitchens and vice versa (Table 41). However, application of analysis of variance did not exhibit any significant relationship between the two variables. Thus the null hypothesis was partially rejected.

The significant positive relationship could be attributed to the fact that the housewives with higher knowledge level regarding the concepts in electricity and lighting, principles of good lighting and lighting products in the market, could comprehend the importance and need for good lighting and probably were more conscious in planning lighting for their kitchens than those with lower knowledge level.

However scrutiny of the data revealed that the illuminances in general were far below the recommended standards. It implies that though the housewives had the knowledge regarding artificial lighting, its application was minimum. It was found that their kitchens were not equipped with appropriate lamps and luminaires to provide adequate illuminance. Housewives who had knowledge regarding the availability of lighting products could have made appropriate selection of lamps and luminaires for their kitchens. However, it appears that the housewives were not willing to spend money for adequately lighting their kitchens. They sacrificed the quality of lighting for keeping the cost of installation and operation down.

H_O $AI._{10}$ There exists no relationship between IuAL and knowledge level of husbands

Knowledge level of husbands was observed to have no significant relationship with IuAL. (Table 41). Thus the null hypothesis was accepted.

H_O $AI._{11}$ There exists no relationship between IuAL and values held by housewives with regard to artificial lighting

No definite relationship was found to exist between each of the selected six values held by housewives with regard to artificial lighting and IuAL (Table 41). However, the computed 't' values indicated that IuAL in kitchens of housewives who earned low scores on comfort value was significantly different at 0.01 level from that of housewives who earned moderate scores on comfort value (Table 45). Therefore the null hypothesis was partially rejected.

Table 45 : Difference between mean IuAL and comfort value held by housewives

Group	Comfort value	N	Mean IuAL
1	Low	29	47.68
2	Moderate	136	58.44
3	High	26	50.28
Mean Contrast	Difference	't' value	Level of significance
1 2	10.76	-2.85	0.01
2 3	8.16	1.88	n.s.
1 3	2.6	-0.50	n.s.

The computed means for each of the six selected values indicated a relative predominance of the comfort value with the mean score of 44.4. The findings revealed that the housewives valued 'comfort' the most with regard to artificial lighting in kitchen (Table 8). There was no consistent pattern in the mean IuAL by comfort value of housewives. The mean IuAL of moderate scorers by comfort value was relatively higher than those of low or high scorers.

Although there were no noticeable differences in the type and wattages of lamps installed across the sample of the study the fact that the housewives in the moderate and high categories by comfort might have made a conscious effort to select appropriate colours and finishes for the various surfaces in the kitchen which might have contributed to relatively higher mean illuminances in their kitchens.

A further exploration of the data revealed that the family income of the housewives in moderate category by comfort was relatively higher as compared to that of those in low and high categories. It could be that the relatively higher family income of housewives in moderate category might nave permitted them to sustain better maintenance of the room surfaces, thus attributing to relatively higher illuminances.

H_O AI.$_{12}$ There exists no relationship between IuAL and perceived level of discomfort experienced of housewives while working in the kitchen

The mean score computed on the perceived level of discomfort of the housewives while working under artificial lighting in the kitchen was 4.5 and the range in scores was 0 to 16. Product Moment correlations computed between IuAL and perceived level of discomfort of the housewives revealed a negative a correlation (r = - 4653) at 0.01 level of significance (Table 41) implying that as IuAL increased discomfort decreased and vice versa.

Table 46: Differences between mean IuAL by perceived level of discomfort

Group	Perceived level of discomfort	N	Mean IuAL
1	Low	25	77.49
2	Moderate	146	54.39
3	High	20	37.98
Mean Contrast	Difference	't' value	Level of significance
1 2	23.1	4.97	0.01
2 3	39.51	4.19	0.01
1 3	16.41	6.93	0.01

The computed 't' values revealed that there was a significant difference in the mean IuAL in the kitchens of housewives by their perceived level of discomfort while working in the kitchen. Kitchens of housewives with low perceived level of discomfort differed significantly (0.01 level) from those with moderate or high perceived level of discomfort with regard to IuAL. A significant difference (0.01 level) was also observed in mean IuAL in kitchens of housewives with moderate and high perceived level of discomfort (Table 46).

The association between IuAL and perceived level of discomfort of the housewives is evident from the analysis of data. As housewives moved from high to low category by discomfort experienced, the mean IuAL of their kitchens increased. It is needless to mention that mean IuAL was far below the recommended values in each categories, i.e. low to high by discomfort experienced. However, majority of the housewives reported to be satisfied with the existing artificial lighting condition in their kitchens, which in general was extremely poor (Table 4, Appendix V). The housewives might not be aware of the fact that well-planned lighting conditions can contribute to improved work efficiency and increased visual comfort. They might not have been exposed to better lighting environment and thus do not realise the inadequacies of the existing lighting conditions in their kitchen and how these inadequacies could cause discomfort at work. This can be further explained by the fact that most of the housewives might have become accustomed and habituated to working under relatively low IuAL that they accepted as a way of life.

H_O AI.$_{13}$ There exists no relationship between IuAL and family income

No significant relationship was found to exist between IuAL and family income. The null hypothesis was accepted (Table 41).

All variables except one variable, viz., tenure of housing was excluded in stepwise regression analysis.

HoA II : There exists no difference in the order of significance in association between the selected situational, personal and family variables on IuAL.

Stepwise regression analysis was computed to test the above hypothesis. All the variables except one variable, viz., tenure of housing were included in stepwise regression analysis. The ordered list of factors revealed the order of variables by their association with IuAL. PLoD, floor area of kitchen, p_{FC}, age of house, UF and

MF emerged out as variables with significant association with IuAL while the remaining variables were observed to be not significant in the presence of the former set of variables in their association with IuAL. On the strength of these observations it was concluded that there existed a difference in the association that existed between these variables and IuAL (Table 47).

Table 47 : The table of F-to-enter and the variables entered in the regression equation in step-wise multiple regression analysis conducted in relation to average general ambient IuAL

Step number	Variables entered	F to enter
1.	Perceived level of discomfort (PLoD)	55.67**
2.	Floor area of kitchen	40.81**
3.	Effective floor cavity reflectance (ρ_{FC})	34.63**
4.	Age of house	29.18*
5.	Utilisation factor (UF)	25.59*
6.	Maintenance factor (MF)	23.29*

* significant at .05 level ** significant at .01 level

The null hypothesis was rejected.

SECTION II

Findings with regard to the data gathered through the experimental work in the simulated kitchen that was designed on the basis of the mean area of field kitchens in the interquartile range are highlighted in this section. The best lit and worst lit kitchens were identified from amongst the kitchens in the interquartile range by area. The average ambient illuminance and illuminance on the work areas in the best and worst lit kitchens thus identified were created in the simulated kitchen in addition to creating illuminance of 500 lx, 300 lx and 100 lx on the work areas. The best lit kitchen had two differential levels of illuminance, namely, 166 lx and 72 lx on its work areas along the platform and the worst lit kitchen had a corresponding average illuminance of 17 lx. The findings pertaining to visual performance of the subjects on (i) visual acuity test i.e., landolt's ring test against different conditions of brightness contrasts and (ii) brownness discrimination test under varying illuminances (500 lx through to 17 lx) are presented. Perceived level of visual comfort (PLoVC) expressed by the subjects while working under the selected illuminances are also discussed.

Thirty-nine female subjects belonging to three selected age categories namely; young (21-30 years), middle (31-40 years) and old (41-50 years) groups constituted the experimental sample. The subjects with comparable visual capabilities (eye sight and colour vision) and visual skills (observation power and rate of visual perception) were selected through preliminary screening. Majority of the subjects in the old age group had eye defects pertaining to near or distant vision, which were rectified by the use of appropriate lens as per the prescription by the ophthalmologist. Every subject was given 10 to 15 minutes to relax before they were subjected to laboratory testing. Prior to administration of tests, the subjects were examined for their clinical condition in terms of temperature, blood pressure and pulse rate to ensure that they were normal and in stable condition of health. The experiments were conducted during a duration of 11 days from 9.00 a.m. to 7.30 p.m. Readings on ambient temperature and humidity were monitored in the simulated kitchen before each experimental session (Table 26 through to 30, Appendix VI).

1.0 ACCURACY FACTOR IN RELATION TO VISUAL PERFORMANCE OF SUBJECTS ON VISUAL ACUITY TEST

The visual performance of the subjects on standard visual acuity test (landolt's ring test) against three brightness contrasts was assessed under each of the six illuminances, namely, 500 lx , 300 lx, 166 lx, 100 lx, 72 lx and 17 lx. The landolt's rings that served as test objects constituted eight different sizes of details subtending visual angles, 11' 17", 9'1", 6' 46", 4' 31", 3' 23", 2' 15", 1' 29" and 1' 8" of arc that were denoted as A, B, C, D, E, F, G and H respectively. These test objects were categorised as large (A, B and C), medium (D and E), medium-small (F) and small (G and H) (Weston, 1949). A list of a sample of different meal related tasks performed in kitchen that were judged as comparable to details of the large, medium, medium small and small test objects are given in Appendix . To create different brightness contrasts (BC_s), three variations were created with one of them having relatively higher brightness contrast (0.89) and the other two having relatively lower brightness contrasts (0.61 and 0.57 respectively). The ratio of the score earned by a subject on the visual acuity test to the maximum score that could be earned on that test is referred as accuracy factor (AF). Accuracy factor for test objects against the backgrounds with the highest to the lowest BC are denoted to as $AF_{BC.1}$, $AF_{BC.2}$ and $AF_{BC.3}$ respectively.

1.1 Accuracy Factor in Relation to Visual Performance on "Large" Test Objects

The test object was identified as large if the detail of the object subtended a visual angle of not less than 6 minutes of arc. Test objects A, B and C of the visual acuity test constituted the large category by visual size. The findings in relation to accuracy factor (AF) for large test objects against BC_1. BC_2 and BC_3 are projected in Fig.12. The mean values of $AF_{BC.1}$ through to $AF_{BC.3}$ for large test objects were found to be more or less similar (more than 0.93) within and between subjects in the young and middle age groups under illuminance of 500 lx, 300 lx and 166 lx. With regard to the performances under illuminance of 100 lx, 72 lx and 17 lx, the mean $AF_{BC.1}$ and $AF_{BC.3}$ for large test objects within and between the subjects in young and middle age groups were comparable to that under illuminance of 500 lx. The $AF_{BC.2}$ for test objects A and B under illuminance of 72 lx for subjects of young and middle age groups was found to be comparable to the $AF_{BC\ 1}$ and $AF_{BC.3}$ under illuminance of 500 lx through to 17 lx, while $AF_{BC.2}$ for test object C was relatively less under illuminance of 72 lx. A relative fall in the $AF_{BC.2}$ was also observed for each of the large test objects under illuminance of 100 lx and 17 lx, the same being more pronounced with reference to test object C.

$AF_{BC.1}$ through to $AF_{BC.3}$ for large test objects of old subjects were comparable under illuminance of 500 lx which were also comparable to $AF_{BC.2}$ and $AF_{BC.3}$ under illuminance of 300 lx as well as to $AF_{BC.1}$ under illuminance of 166 lx . On the other hand, $AF_{BC\ 1}$ for large test objects of subjects in old age group under illuminance

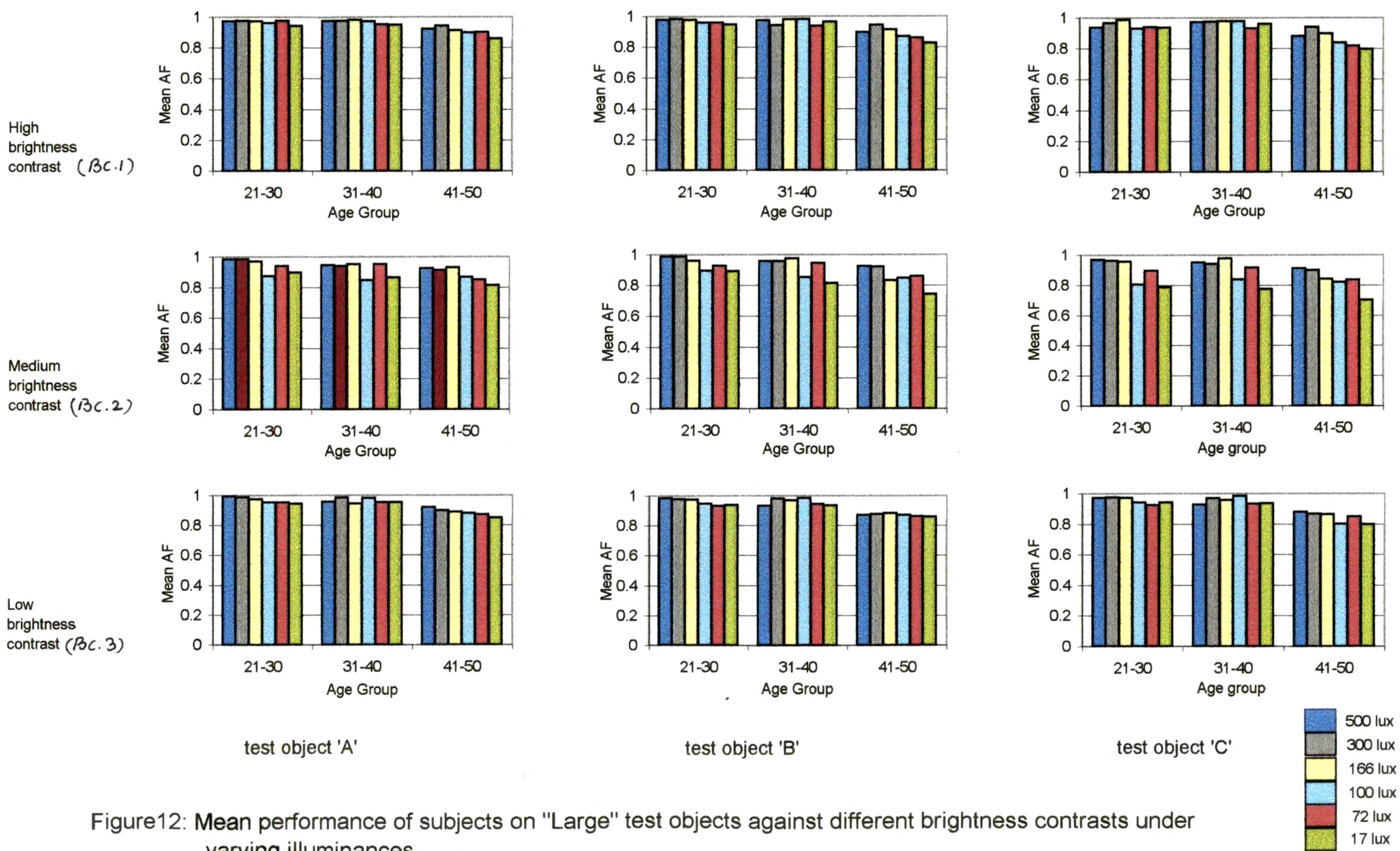


Figure12: Mean performance of subjects on "Large" test objects against different brightness contrasts under varying illuminances.

of 300 lx was better than the same under illuminance of 500 lx and 166 lx. The $AF_{BC\,2}$ and $AF_{BC.3}$ for test object C of subjects under illuminance of 166 lx was reduced by 10 per cent as compared to $AF_{BC\,1}$ through to $AF_{BC\,3}$ under illuminance of 500 lx and 300 lx. Similar trend was observed in case of $AF_{BC.2}$ for test object B under illuminance of 166 lx.

The $AF_{BC\,1}$ for test objects A and B under illuminance of 100 lx and 72 lx and on test object A under illuminance of 17 lx of old subjects ranged between .85 to .88, implying a drop by 5 per cent as compared to that under illuminance of 500 lx. Similar observations were found with regard to $AF_{BC.3}$ for test objects A and B under illuminance of 100 lx, 72 lx and 17 lx. A drop approximately by 10 per cent in $AF_{BC.1}$ for test object B under illuminance of 17 lx and, also in $AF_{BC.1}$ and $AF_{BC.3}$ for test object C under illuminance of 100 lx and 17 lx were observed in comparison to that under illuminance of 500 lx. The mean $AF_{BC.2}$ for all the large test objects for the old subjects were relatively low in comparison to the $AF_{BC\,1}$ and $AF_{BC.3}$ for the same under illuminance of 100 lx, 72 lx and 17 lx. A drastic fall in $AF_{BC\,2}$ by 20-25 per cent was observed for test objects B and C under illuminance of 17 lx when contrasted with illuminance of 500 lx, the mean values being 0.74 and 0.70 respectively.

In general, the inter-age group comparisons revealed that the visual performance of subjects in young and middle age group on large test objects across the varying illuminances and brightness contrasts were more or less comparable. However, there were drastic differences in the mean performances of the old subjects, the differences being more prominent under lower levels of illuminances, and in case of test object C (Figs.16, 17 and 18).

1.2 Accuracy Factor in Relation to Visual Performance on "Medium" Size Test Objects

Objects of medium size are those which subtend a visual angle ranging from 3 minutes of arc or more to less than 6 minutes of arc. The test objects D and E of the visual acuity test were identified as medium size test objects. Analysis of data revealed that $AF_{BC.1}$ through to $AF_{BC\ 3}$ for test objects D within and between the subjects in young and old age groups under illuminance of 500 lx, 300 lx and 166 lx were more or less similar to each other and also to corresponding values on large test objects under the same illuminances, the mean values on each ranging between 0.94 to 0.96. The AF for test object E of the two younger age groups under the same test conditions ranged between 0.88 to 0.93 except $AF_{BC\ 1}$ of middle age group under illuminance of 166 lx. Under illuminance of 100 lx, 72 lx and 17 lx , $AF_{BC\ 1}$ for test object D within and between the subjects in young and middle age groups range between 0.90 to 0.94, implying a negligible fall as compared to that of the $AF_{BC.1}$ under higher illuminances (500 lx, 300 lx and 166 lx). The $AF_{BC.1}$ for test object D under illuminance of 100 lx, 72 lx and 17 lx were comparable to each other with mean values ranging between 0.89 to 0.96 and also to $AF_{BC\ 1}$ for test object E under illuminance of 100 lx and 17 lx. However, $AF_{BC.1}$ for test object E under illuminance of 72 lx was distinctly low with a mean value of 0.83. The $AF_{BC\ 2}$ and $AF_{BC.3}$ within and between the subjects of young and middle groups by age were still lower, especially with regard to test objects D and E in medium brightness contrast under illuminance of 100 lx and 17 lx (0.73 to 0.81), and test object E in low brightness contrast under 17 lx (0.71 to 0.80). The mean performance on these test objects declined by about 25 per cent as compared to those under illuminance of 500 lx. Hence it was found that there was no regular

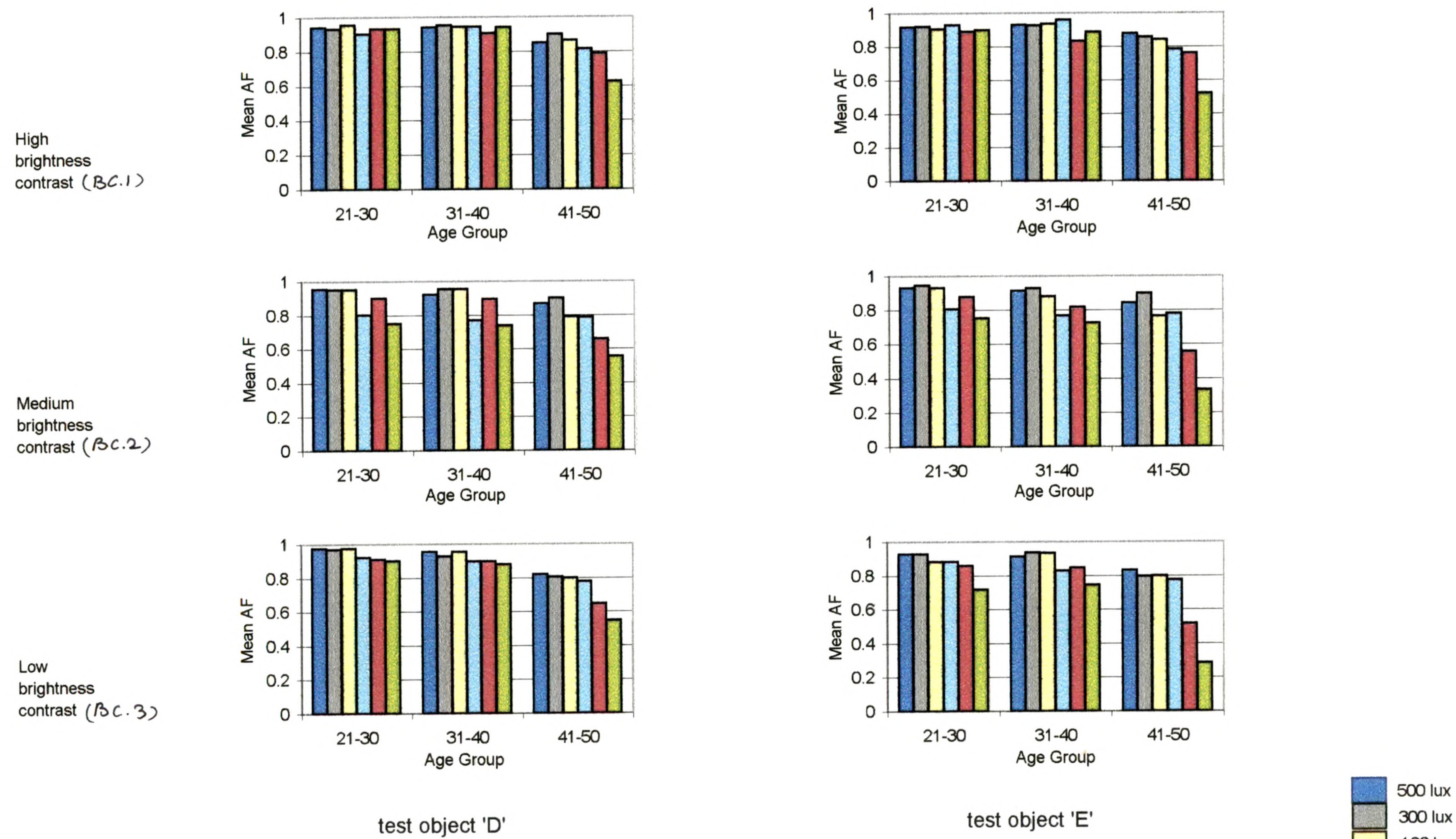


Figure 13: Mean performance of subjects on "Medium" test objects against different brightness contrast under varying illuminances.

trend in the mean performances within and between the subjects in young and middle age groups with each successive decrease in the lower illuminance, namely, 100 lx, 72 lx and 17 lx (Fig. 13).

The $AF_{Bc.1}$ and $AF_{Bc\ 2}$ of old subjects for medium size test objects under illuminance of 500 lx and 300 lx, and $AF_{BC.1}$ under illuminance of 166 lx were characterised by a negligible decline, with mean values ranging between 0.84 to 0.90, as compared the mean AF between 0.90 to 0.92 on larger test objects under illuminance of 300 lx and 166 lx. However, a noticeable drop in the $AF_{BC.2}$ (0.78) was observed for test objects D and E under illuminance of 166 lx. On the other hand, the decline in $AF_{BC\ 3}$ was more pronounced (mean values ranging between 0.79 to 0.83) for mèdium size test objects under illumances of 500 lx, 300 lx and 166 lx of as compared to the $AF_{BC.1}$ and $AF_{BC.2}$ under similar illuminances.

With regard to the lower illuminances, a successive fall in the performance of old subjects was perceived with decrease in illuminances. The performances of these subjects were adversely affected under the lower illuminances. The mean $AF_{BC.1}$ through to $AF_{BC\ 3}$ under illuminance of 100 lx and mean $AF_{BC.1}$ under illuminance of 72 lx for medium size test objects ranged between 0.76 to 0.82 , which were less approximately by 10 to 15 per cent as compared to those under illuminance of 500 lx, while the mean $AF_{BC.2}$ and $AF_{BC.3}$ for these test objects under illuminance of 72 lx ranged between 0.52 to 0.66 indicating a drop by 30 to 40 per cent as compared to those under illuminance of 500 lx. The mean $AF_{BC.1}$ for test object D of old subjects under illuminance of 17 lx was 0.63 while the mean $AF_{BC.2}$ and $AF_{BC.3}$ under same test conditions was about 0.55 , characterised by a drop of 30 per cent and by little less than 40 per cent respectively as compared to those under illuminance of 500 lx. The mean $AF_{BC.1}$, $AF_{BC.2}$ and $AF_{BC.3}$ for test object E under illuminance of 17 lx were estimated to be 0.52, 0.33 and 0.28 respectively with corresponding decline by 40 per cent, 60 per cent and 65 per cent as compared to those under illuminance of 500 lx.

Comparisons amongst the three age groups indicated negligible differences between the performances of the subjects in young and middle age groups across the six illuminances and brightness contrasts. However, the differences were remarkably high with regard to performances of older subjects on medium size test objects when compared with the younger two groups the same being more prominent on test object E against BC.2 and BC.3 under illuminance of 72 lx and 17 lx. (Figs.16,17 and 18)

1.3 Accuracy Factor in Relation to Visual Performance on "Medium-Small" Test Objects

Object in medium-small size subtended a visual angle of less than 3 minutes but not less than 1.5 minutes of arc. The test object F of the visual acuity test was classified as medium-small. The mean AF for test object F for each brightness contrast from BC.1 through to BC.3 within and between the subjects of young and middle age groups under illuminance of 500 lx and 300 lx ranged between 0.90 to 0.91, 0.86 to 0.90 and 0.84 to 0.90 respectively. The mean $AF_{BC.1}$ through to $AF_{BC.3}$ for test object F of young age group under illuminance of 166 lx and $AF_{BC.1}$ under illuminance of 100 lx were more or less parallel to those under illuminance of 500 lx and 300 lx. However, the $AF_{BC.2}$ and $AF_{BC.3}$ for test object F of young age group were found to be adversely affected under illuminance of 100 lx with a mean value 0.75 and 0.84 respectively. The mean $AF_{BC.1}$ through to $AF_{BC.3}$ for medium-small test object of the young subjects revealed a

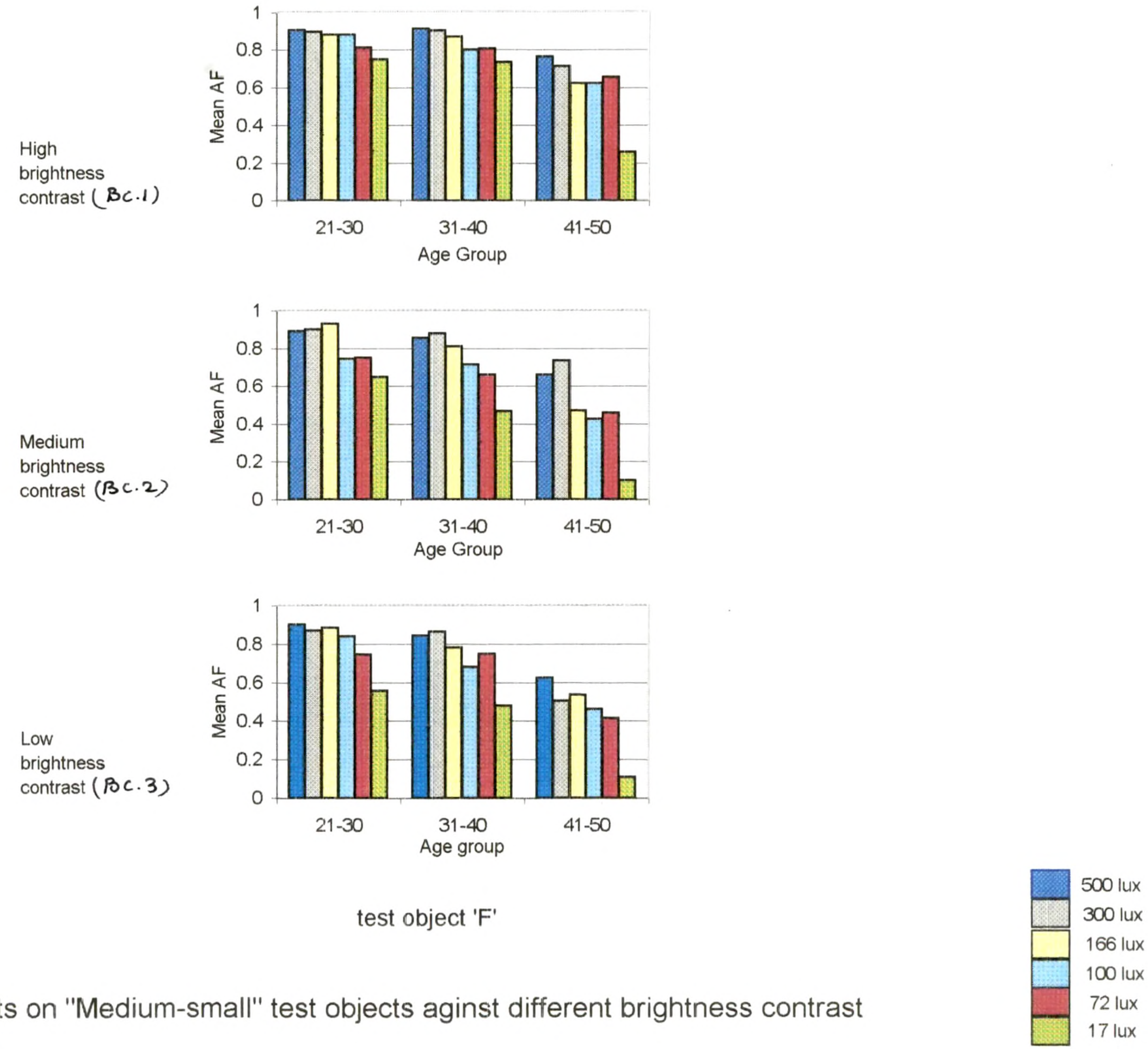


Figure 14: Mean performance of subjects on "Medium-small" test objects aginst different brightness contrast under varying illuminances.

further decline under illuminance of 72 lx and as seen in the Fig.14 with the mean $AF_{BC\,3}$ being the least.

As for the performances of the subjects of middle age group on test object F under illuminance of 166 lx, the mean $AF_{BC\,1}$ reduced by less than 5 per cent while the mean $AF_{BC.2}$ and $AF_{BC.3}$ dropped by about 10 per cent as compared to those under illuminance of 500 lx. The $AF_{BC\,1}$ through to $AF_{BC\,3}$ for test object F of the same subjects under illuminance of 100 lx were characterised by a decline by 12 per cent, 16 per cent and 20 per cent respectively as compared to those under illuminance of 500 lx. The mean $AF_{BC.1}$ for test object F of this age group projected further decline in performance by 23 per cent under illuminance of 72 lx and 45 per cent under illuminance of 17 lx as compared to those under illuminance of 500 lx. The mean $AF_{BC.2}$ and $AF_{BC.3}$ for test object F under illuminance of 72 lx and 17 lx F were still lower (Fig. 14).

The performance of old subjects was noticeably low on medium-small test objects as compared to the two younger age groups. The mean $AF_{BC.1}$ for test object F under illuminance of 500 lx was less than 0.80 while the mean $AF_{BC.2}$ and $AF_{BC.3}$ under same test conditions were 0.65 or less. The mean $AF_{Bc\,1}$ and $AF_{BC.2}$ under illuminance of 300 lx were estimated to be a little more than 0.70 while the mean $AF_{BC.3}$ was only 0.50. The mean $AF_{BC.1}$ for test object F of old subjects under illuminance of 166 lx, 100 lx and 72 lx were more or less similar to each other with mean values being a little more than 0.60, which were distinctly higher than the mean $AF_{BC.2}$ and $AF_{BC\,3}$. The performances under illuminance of 17 lx were tremendously reduced in the case of old subjects and the estimated AF were as low as 0.25 and 0.10 each with regard to performance against BC.1, BC.2 and BC.3 respectively.

The differences in the visual performance between the subjects in young and middle age groups were visible on test object F under illuminance of 166 lx through to 17 lx, the differences being more pronounced when tests were performed under illuminance of 72 lx and 17 lx, against BC.2 and BC.3. When mean AF of old age group under illuminance of 500 lx through to 17 lx for test object F against the three brightness contrasts were compared with those respectively of the two younger age groups, a progressive decline was observed in each of the mean values of AF (Figs.16, 17 and 18). The decline in mean AF was more pronounced in the case of tests performed against BC.3 (30 through to 80 per cent) as compared to that against BC.1 (15 through to 65 per cent), and BC. 2 (25 through to 85 per cent).

1.4 Accuracy Factor in Relation to Visual Performance on "Small" Test Objects

The objects that were classed as small subtended a visual angle less than 1.5 minutes down to a limit of 50 seconds. Test objects G and H of visual acuity test were categorised as small. Distinct differences were found in the visual performances on the small test objects amongst the three age groups across the three brightness contrasts under each of the illuminances. The visual performance of subjects in the young age group on test object G under higher illuminaces (500 lx, 300 lx and 166 lx) did not reveal much noticeable differences within each of the brightness contrast although distinct differences were observed in their performance between the three different brightness contrasts under these illuminances as evidenced by the mean AF values (Fig 15). The mean $AF_{BC.1}$ through to $AF_{BC.3}$ for test object G of subjects in young age group under these higher illuminance were about 0.90, 0.85 and 0.80

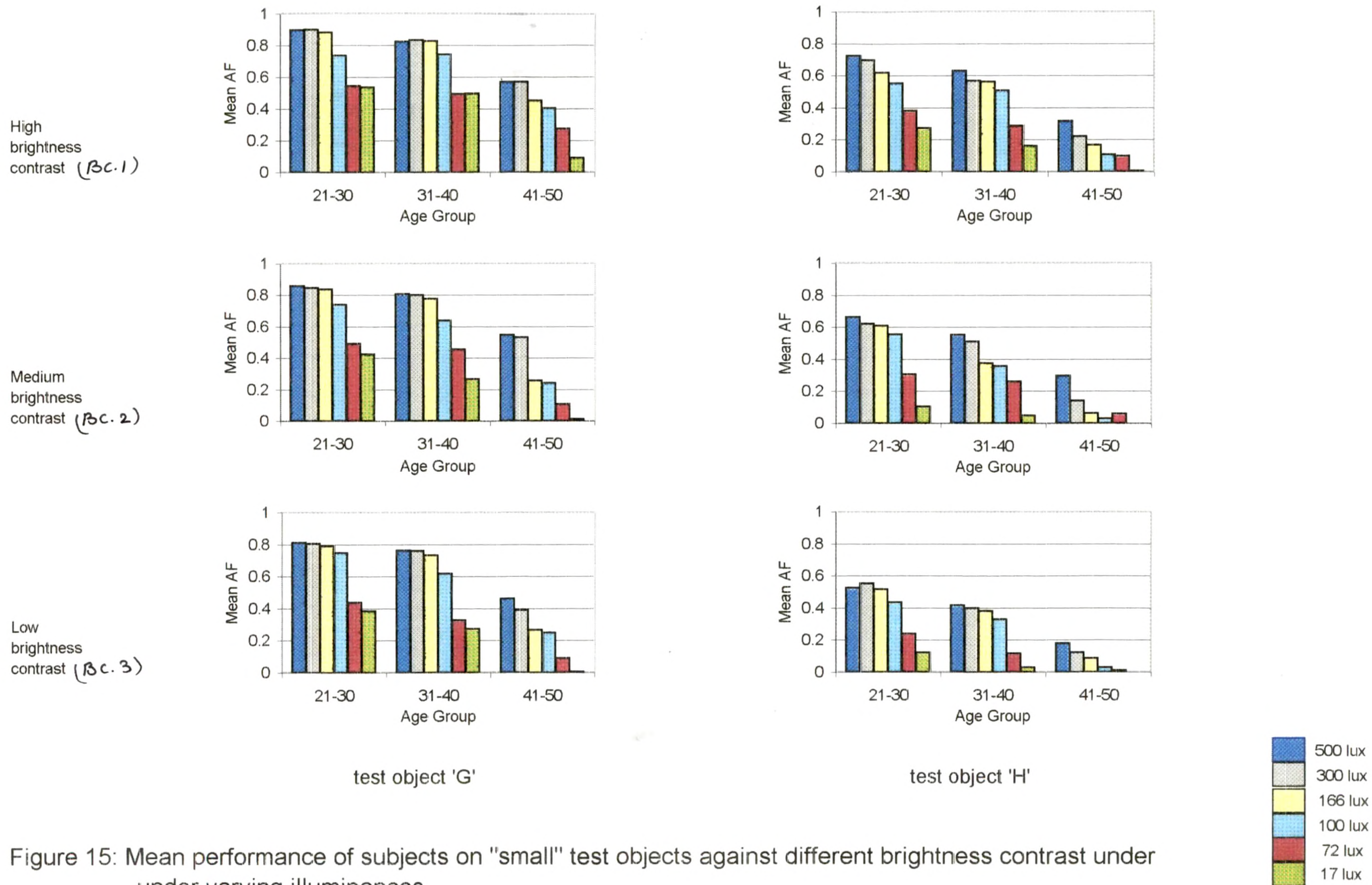


Figure 15: Mean performance of subjects on "small" test objects against different brightness contrast under under varying illuminances.

respectively. The mean AF for test object G of the young subjects under illuminance of 100 lx declined by a little less than 20 per cent as compared to their $AF_{BC.1}$ under illuminance of 500 lx. However, the variations found in mean AF against the three brightness contrasts under illuminance of 100 lx were negligible. The $AF_{BC.1}$ for test object G was comparable under illuminance of 72 lx and of 17 lx with mean value of 0.54, while the mean $AF_{BC.2}$ and $AF_{BC.3}$ were relatively lower under illuminance of 17 lx as compared to that under illuminance of 72 lx. A distinct decrease in the mean AF for test object H of young subjects, with a drop in illuminance level (500 lx through to 17 lx) and a decrease in brightness contrast (BC.1 through to BC.3) was observed. The $AF_{BC.1}$ of 0.73 for object H under illuminance of 500 lx tumbled down to $AF_{BC.3}$ of 0.12 under illuminance of 17 lx .

The trend in the mean performances on test objects G and H of the subjects in middle age group was more or less comparable to that of the young subjects as observed through mean AF (Figs.16,17 and 18). However, mean AF values of subjects of middle age group were noticeably low under different illuminances and brightness contrasts as compared to that of the younger age group except in case of test object G where the $AF_{BC.1}$ of the former group under illuminance of 100 lx was similar to that of subjects in young age group. The percentage differences in the AF for the two age groups ranged between 5 to 15 per cent,. The differences were remarkably higher for BC.2 and BC.3 under lower illuminances (72 lx and 17 lx), where the drop in AF of subjects in middle age group ranged between 20 to 30 per cent as compared to that of young subjects.

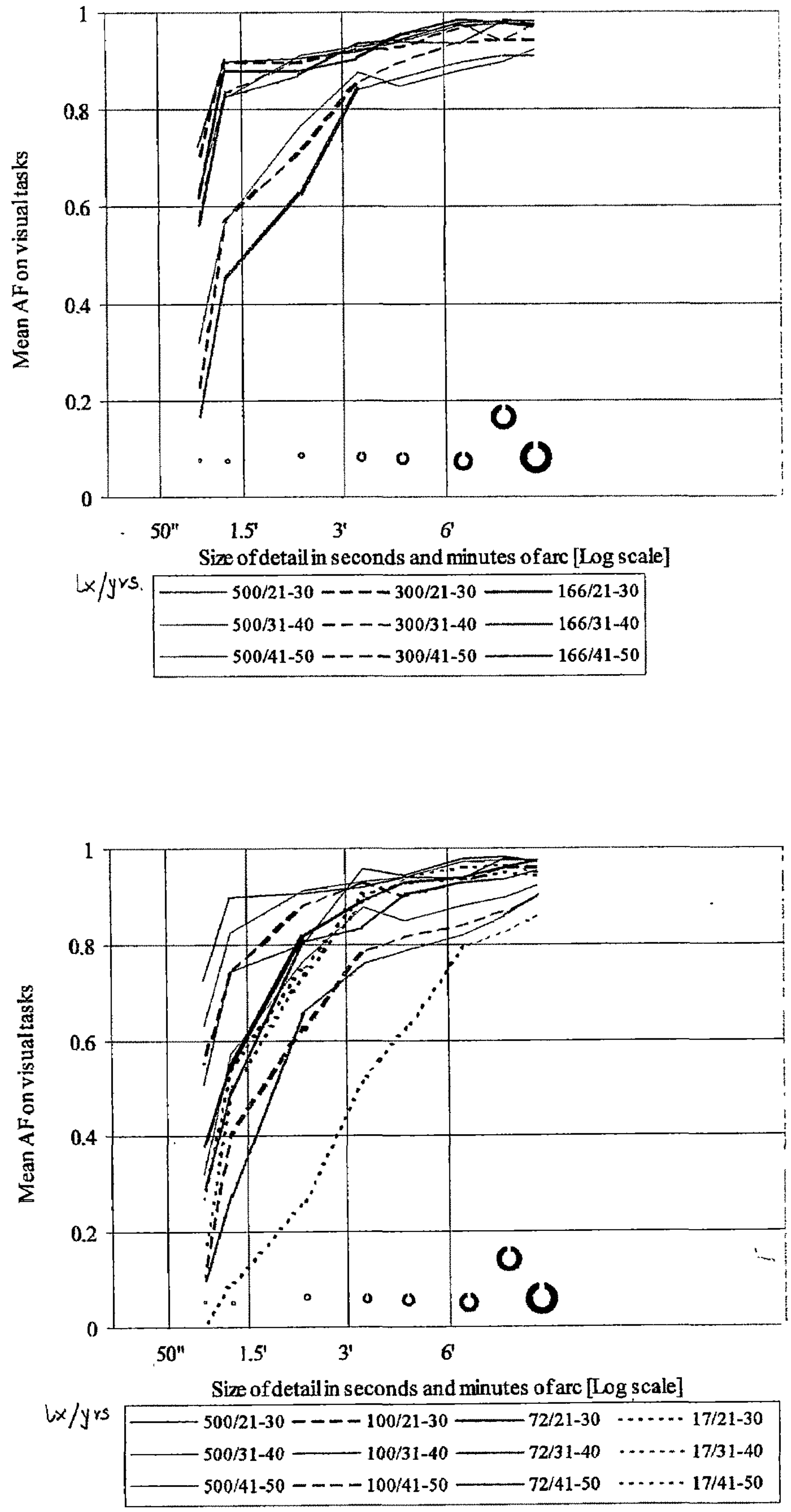
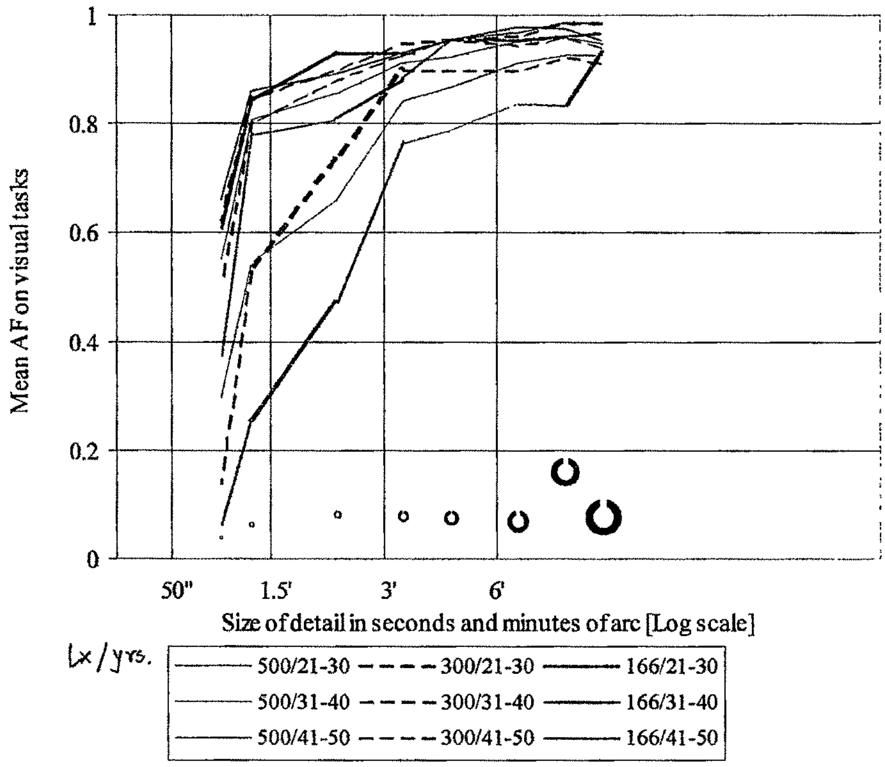


Figure 16 Mean performance(AF) of subjects on visual acuity tests against high brightness contrast in relation to visual angle subtended by test objects.



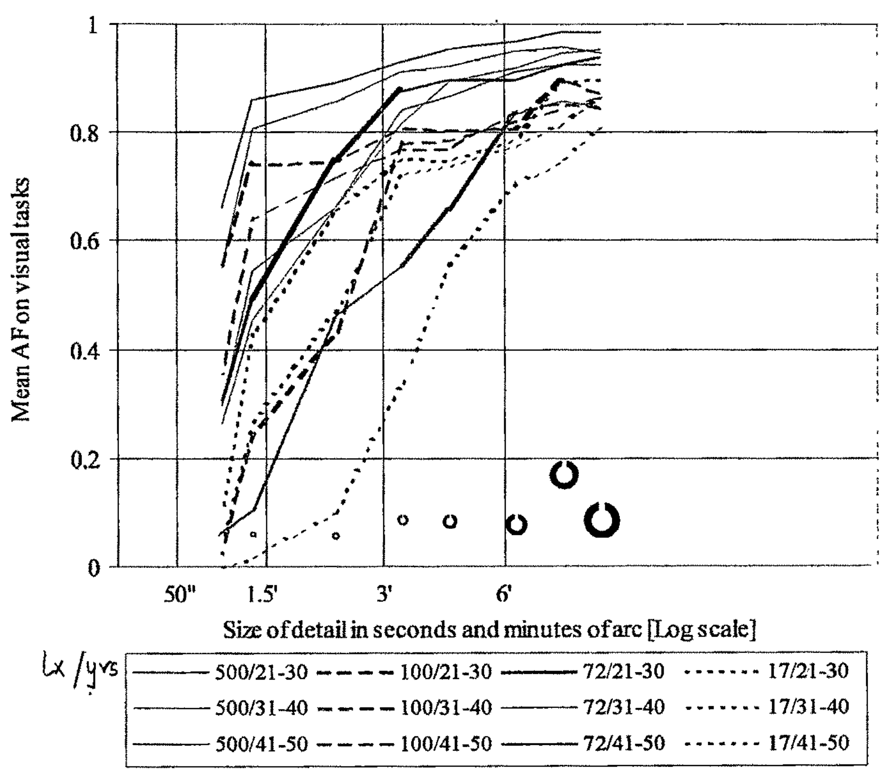
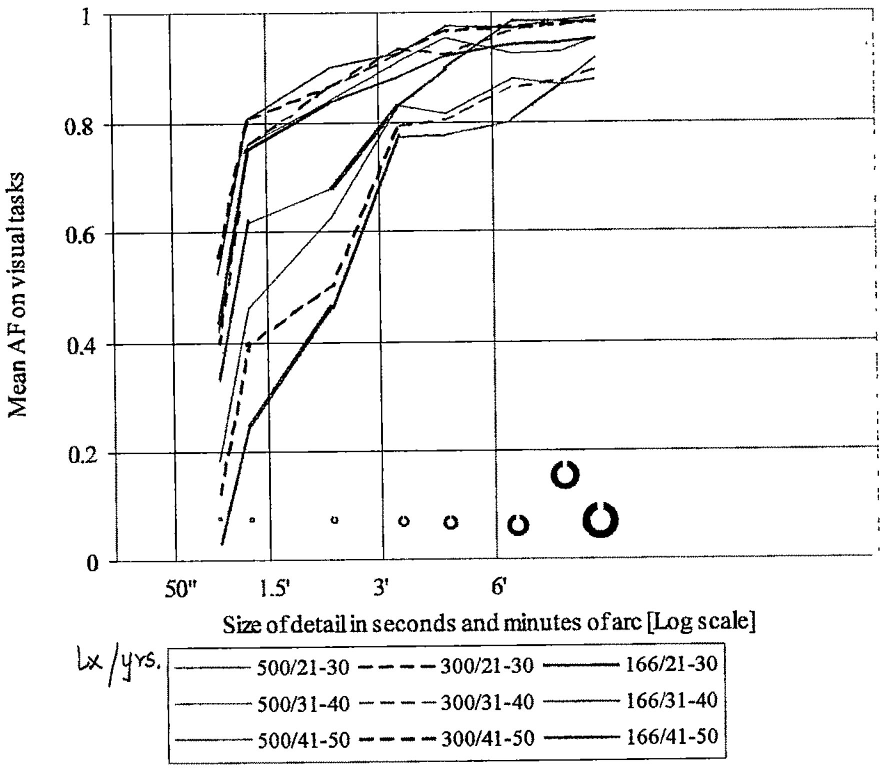


Figure 17 Mean performance (AF) of subjects on visual acuity tests against medium brightness contrast in relation to visual angle subtended by test objects.



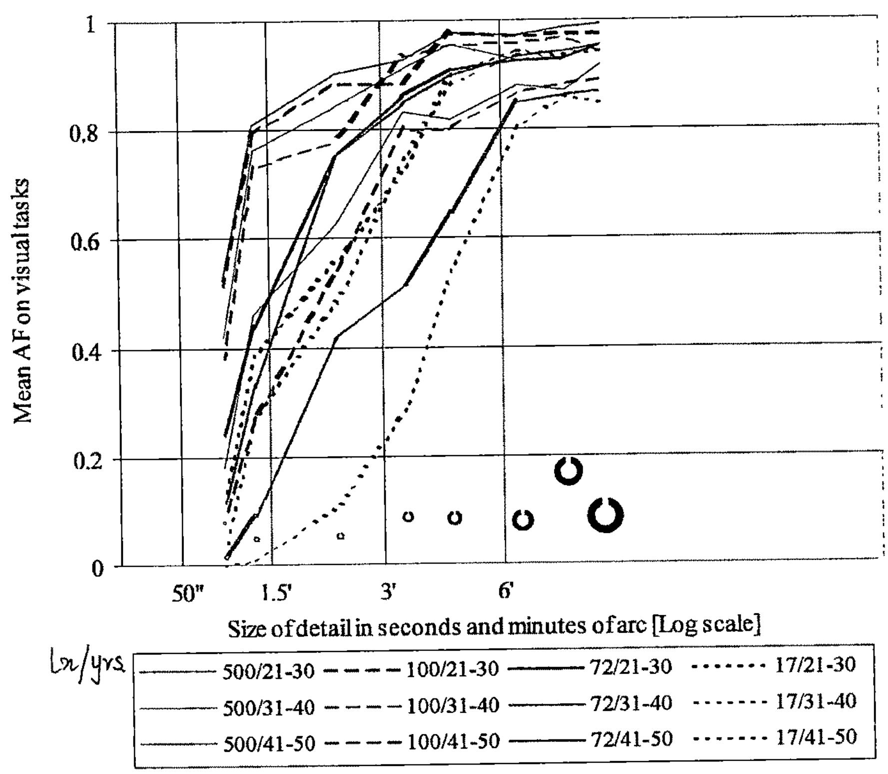


Figure 18 Mean performance(AF) of subjects on visual acuity test against low brightness contrast in relation to visual angle subtended by test objects.

The performance of old subjects on small test objects in general was extremely low. The mean $AF_{BC.1}$ for test objects G and H under illuminance of 500 lx were 0.57 and 0.32 respectively. The mean $AF_{BC.3}$ and $AF_{BC\ 3}$ were still lower under the same test conditions. The mean $AF_{BC\ 1}$ through to $AF_{BC.3}$ for test objects G and H was adversely affected by each successive drop in illuminance. It was observed that the AF for test object H was distinctly low as compared to that for test object G across all the illuminances and brightness contrasts. Under illuminance of 72 lx, the old subjects were not able to perform on test object H while the same was true for both the test objects (G and H) under illuminance of 17 lx.

2.0 LEVEL OF VISUAL PERFORMANCE OF SUBJECTS ON VISUAL ACUITY TEST (LOP I) AGAINST DIFFERENT BRIGHTNESS CONTRASTS UNDER VARYING ILLUMINANCES

The level of visual performance of subjects was ascertained on visual acuity test comprising of landolt's rings of selected from each of the four categories by visual size (angle), namely, large (test object 'A') , medium (test object 'D'), medium-small (test object 'F') and small (test object 'G') against each of the three selected brightness contrasts under each of the six selected illuminances (LoP I). The sum of level of visual performance on large, medium, medium-small and small test objects reflected the overall LoP I (OLoP I).

The data of 39 subjects on LoP I against all the three brightness contrasts and six illuminances were pooled together to study the combined effect of brightness contrast and illuminance.

The data were dealt with separately for (i) all the three brightness contrasts and (ii) all the six illuminances to study the main effect of illuminance and brightness contrasts respectively. The distribution of the sample by pooling data on LoP I against all the brightness contrasts under all the illuminances are presented first. This is followed by data on LoP I against three brightness contrasts under each illuminance as well as under all the illuminances put together for each brightness contrast.

2.1 LoP I under all the Brightness Contrasts and Six Illuminances Pooled together

A successive fall in the mean scores was observed on LoP I against different brightness contrasts under varying illuminances across the four selected test objects, namely large (LoP $I_{L\ BC\text{-}L}$), medium (LoP $I_{L\ BC\text{-}M}$), medium-small (LoP $I_{L.BC\text{-}MS}$) and small (LoP $I_{L\ BC\text{-}S}$) with decreasing visual size of the details subtended by these test objects. A progressively increasing value of S.D. indicated that the variation in the mean scores among the subjects increased with decreasing visual size of the details subtended by the test objects. Analysis of data revealed that relatively a smaller proportion (13 to 16 per cent) of the subjects earned low mean scores on OLoP $I_{L\ BC}$, LoP $I_{L\ BC\text{-}L}$, LoP $I_{L.BC\text{-}M}$ and LoP $I_{L.BC\text{-}MS}$, while 80 to 90 per cent earned moderate mean scores on the same with none or negligible proportion earning high scores. With regard to LoP $I_{L.BC\text{-}S}$, about one-seventh of the subjects each could be seen as revealing high and low mean scores respectively (Table 48).

Table 48: Distribution of subjects by the mean scores on their LoP I under all the different brightness contrasts and six illuminances pooled together.

Group	OLoP $I_{L.BC}$		LoP $I_{L.BC-L}$		LoP $I_{L\ BC-M}$		LoP $I_{L.BC-MS}$		LoP $I_{L\ BC-S}$	
	N	%	N	%	N	%	N	%	N	%
Low	6	15.4	6	15.4	5	12.8	6	15.4	6	15.4
Moderate	32	82.1	33	84.6	34	87.2	31	79.5	28	71.8
High	1	2.6	-	-	-	-	2	5.1	5	12.8
Total	39		39		39		39		39	
Mean	1755.21		537.56		498.54		402.87		316.23	
S.D.	345.42		36.17		67.37		121.71		135.24	

2.2 LoP I against all the Brightness Contrasts Pooled together under each Illuminance

A progressive decline in mean LoP I_{BC-MS} and LoP I $_{BC-S}$ was observed with each successive decrease in illuminance . The mean LoP I_{BC-MS} dropped by 45 per cent and mean LoP I_{BC-S} by 60 per cent under illuminance of 17 lx as compared to those under 500 lx. High values of S.D. indicated wide variations among the subjects in their LoP I_{BC-L} and LoP I_{BC-M}, under low illuminances and LoP I_{BC-MS} and LoP I_{BC-S} across all the illuminances.

The distribution of the subjects in low, moderate and high categories by their mean scores is projected in Table 49. It was found that the distribution of subjects by their mean scores on LoP I_{BC-L} and LoP I_{BC-MS} under illuminances of 500 lx, 300 lx and 166 lx

Group	LoP I_{BC-MS}												LoP I_{BC-S}											
	500 lx		300 lx		166 lx		100 lX		72 lx		17 lx		500 lx		300 lx		166 lx		100 lx		72 lx		17 lx	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Low	5	12.8	5	12.8	5	12.8	6	15.4	6	15.4	10	25.6	4	10.3	6	15.4	8	20.5	8	20.5	9	23.1	10	25.6
Moderate	34	87.2	34	87.2	34	87.2	24	61.5	29	74.4	20	51.3	32	82.1	32	82.1	27	69.2	25	64.1	23	59.0	20	51.3
High	-	-	-	-	-	-	9	23.1	4	10.3	9	23.1	3	7.7	-	2.6	4	10.3	6	15.4	7	17.9	9	23.1
Total	39		39		39		39		39		39		39		39		39		39		39		39	
Mean	78.56		77.46		72.49		65.87		64.59		43.90		69.72		68 64		62.15		54.67		34.46		26.59	
S.D.	17.66		19.52		23.38		24.63		20.74		27.92		24.22		26.55		28.75		28.49		20.67		22.54	

as well as on LoP I_{BC-M} under illuminance of 500 lx and 166 lx was more or less comparable, where in about 80 to 90 per cent of the subjects belonged to the moderate category while 10 to 20 per cent of them belonged to the low category. Similar distribution of subjects was observed in their LoP I_{BC-L} under illuminances of 17 lx and LoP I_{BC-M} under illuminance of 72lx and 17 lx. With regard to the LoP I_{BC-S}, the proportion of subjects in the moderate category progressively declined with each successive fall in illuminance while the proportion of subjects in the low and high category increased with relatively higher concentration in former category.

2.3 LoP I against each Brightness Contrast under all the Six Illuminances Pooled together

The mean scores on overall LoP I (OLoP I_L) and LoP I of the subjects under varying illuminances on large (LoP I_{L-MS}), medium (LoP I_{L-M}), medium-small (LoP I_{L-MS}) and small (LoP I_{L-S}) test objets were distinctly high against high brightness contrasts (BC.1) as compared to medium (BC.2) and low (BC.3) brightness contrasts (Table 50). It was observed that the mean LoP I_{L-L} and LoP I_{L-M}, were relatively higher against BC.3 as compared to BC.2 while the trend was reversed in case of mean LoP I_{L-MS} and LoP I_{L-S}. Further, strikingly high S.D. were observed in the case of LoP I_{L-MS} and LoP I_{L-S}. It was observed that relatively smaller proportion (10 to 20 per cent) of the subjects earned low mean scores on LoP I_{L-L} and LoP I_{L-M} against BC.1 and BC.2 respectively. Nearly 80 to 90 per cent earned moderate scores on the same.

Nearly three-fourth of the subjects revealed moderate LoP I_{L-MS} against BC.1 and BC.3 and LoP I_{L-S} against BC.1, while about one-seventh of them exhibited low scores on the same. In contrast to this only 5 to 8 per cent of subjects belonged to category of high

Table 50 : Distribution of mean scores of subjects on their LoP I against each brightness contrast under all the six illuminances pooled together

Group	OLoP I_L						LoP I_{L-L}						LoP I_{L-M}					
	BC.1		BC.2		BC.3		BC.1		BC.2		BC.3		BC.1		BC.2		BC.3	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Low	6	15.4	6	15.4	7	17.9	5	12.8	7	17.9	7	17.9	5	12.8	5	12.8	6	15.4
Moderate	31	79.5	27	69.2	31	79.5	34	87.2	29	74.4	32	82.1	33	84.6	33	84.6	33	84.6
High	2	5.1	6	15.4	1	2.6	-	-	3	7.7	-	-	1	2.6	1	2.6	-	-
Total	39		39		39		39		39		39		39		39		39	
Mean	618.73		568.64		567.85		181.82		175.51		180.23		171.38		161.15		166.00	
S.D.	108.62		122.07		120.64		12.04		13.02		13.42		19.79		23.36		26.79	

Group	LoP I_{L-MS}						LoP I_{L-S}					
	BC.1		BC.2		BC.3		BC.1		BC.2		BC.3	
	N	%	N	%	N	%	N	%	N	%	N	%
Low	6	15.4	6	15.4	6	15.4	6	15.4	7	17.9	6	15.4
Moderate	31	79.5	28	71.8	30	76.9	30	76.9	26	66.7	27	69.2
High	2	5.1	5	12.8	3	7.7	3	7.7	6	15.4	6	15.4
Total	39		39		39		39		39		39	
Mean	147.28		129.10		126.49		118.23		102.87		95.13	
S.D.	37.86		43.57		42.84		45.11		49.64		44.06	

scorers. Further, while about 72 per cent of the subjects belonged to moderate category by their LoP $I_{L\ MS}$ nearly two-third were observed to be so in their LoP $I_{L\ S}$ against BC.2. More or less similar proportions belonged to either of the extreme levels in their LoPI I_{L-MS} and LoP $I_{L\ S}$ against BC2.

3.0 LEVEL OF VISUAL PERFORMANCE OF SUBJECTS ON BROWNNESS DISCRIMINATION TEST (LOP II) UNDER VARYING ILLUMINANCES

The brownness discrimination test constituted 14 samples of semolina that had been roasted to varying degrees of brownness apart from a sample of raw item. The subjects of the experiment were required to rank order the given samples by their degree of brownness under each of the six illuminances, through visual inspection. The possible range in the score on the test was between 15 to 30. Analysis of the data revealed that the mean score earned by the subjects on the brownness discrimination test ranged between 25.6 to 27.0 under the illuminance of 166 lx through to of 500 lx among all the three age groups. In other words, the subjects were able to correctly identify 12 to 13 samples of semolina by their degree of brownness under these three illuminances. Similar scores were earned b the subjects in young and middle age groups under illuminance of 100 lx. However, the mean scores ranged between 24.0 to 25.2 for the old subjects under the illuminance of 100 lx and 72 lx, and for the two younger groups under illuminance of 72 lx. It was observed that the mean scores under illuminance of 17 lx of subjects in young, middle and old age categories were 22.92, 21.85 and 21.54 respectively ; implying that the subjects could correctly

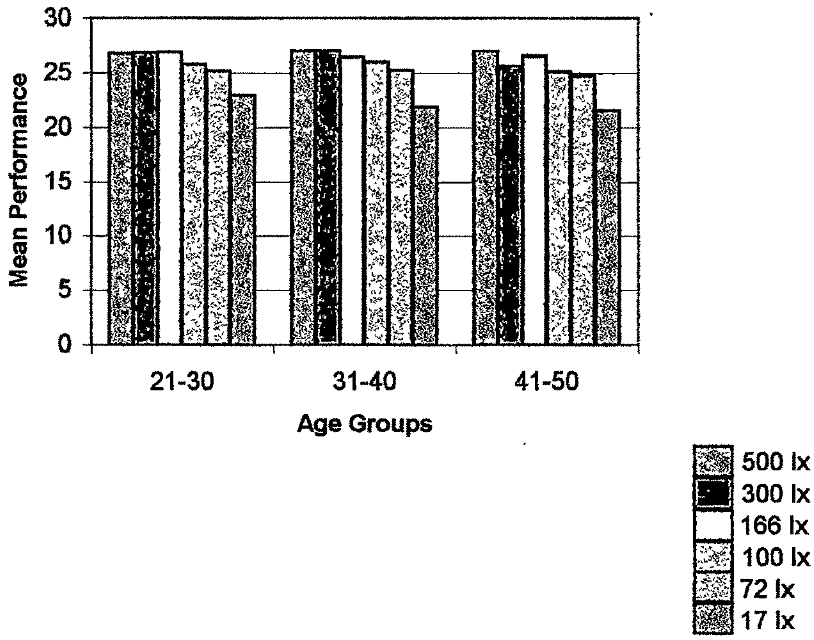


Figure 19: Mean performance of subjects of different age groups on brownness discrimination test under varying illuminances.

rank order only 7 to 8 samples of semolina by its degree of brownness (Figure 19).

The findings of the brownness discrimination test revealed that the ability of the subjects in the old group to discriminate finer differences in brownness was not adversely affected under illuminance of 166 lx through to illuminance of 500 lx. In the case of subjects in the young and middle age groups similar observation could be extended upto illuminance of 100 lx. However, the efficiency of correct identification of varying degrees of brownness reduced drastically under illuminance of 17 lx.

4.0 PERCEIVED LEVEL OF VISUAL COMFORT (PLOVC) OF THE SUBJECTS UNDER VARYING ILLUMINANCES

On completion of the visual acuity test and colour discrimination test, the subjects were administered a questionnaire to assess their perception regarding visual comfort experienced in performing the tests under each of the six selected illuminances in the simulated kitchen. The perceived level of visual comfort (PLoVC) of the subjects was determined in terms of subjective assessment of adequacy of illuminance and brightness level, pleasantness created by lighting, perception of glare and shadow under the six selected experimental conditions. Each aspect was measured on a five point scale with the possible range in total score being 6 to 30.

Figure 20 shows the median and inter quartile ratings of PLoVC under different illuminances. The median value indicated a decline in PLoVC of the subjects with each successive drop in illuminance from 500 lx to 17 lx, the decline in PLoVC being more sharp under illuminances of 100 lx, 72 lx and 17 lx. The distribution of subjects by their scores on PLoVC was found to be widely scattered under the illuminance of 100 lx while that under illuminance of 300 lx was closely packed. A comparison among the subjects in three age groups, revealed that the differences in the mean scores on PLoVC across the six illuminances were relatively wider for subjects in young and middle age groups as compared to those in old age group. The decline in the median PLoVC scores of subjects in young and middle age groups between illuminance of 300 lx to 17 lx ranged from 8 to 50 per cent in comparison to their PLoVC scores under illuminance of 500 lx ; the median value being 25 each under 500 lx ; 23 each under 300 lx, and 12 and 13 under 17 lx of the subjects of the two respective age groups. On the other hand, the drop in median scores ranged between 10 to 40 per cent for the subjects in old age group, with their median score under illuminance of 500 lx, 300 lx and 17 lx being 25.3, 23.2 and 15.2 respectively. The figures clearly depict that the differences in the median scores on PLoVC between illuminance of 500 lx and 300 lx were negligible. There were a few subjects in the old age group who reported that the simulated kitchen was flooded with excess light under the illuminance of 500 lx and they indicated a preference for illuminance of 300 lx. No such preference was revealed by the subjects in the two younger age groups and they reported that the illuminance of 500 lx was more comfortable to work.

It was found that the PLoVC of old subjects was relatively higher as compared to the two younger age groups, even under low illuminances. Such an observation can be accounted for by the fact that the old subjects perceived the lower illuminances having closer resemblance to those under which they were habituated to work.

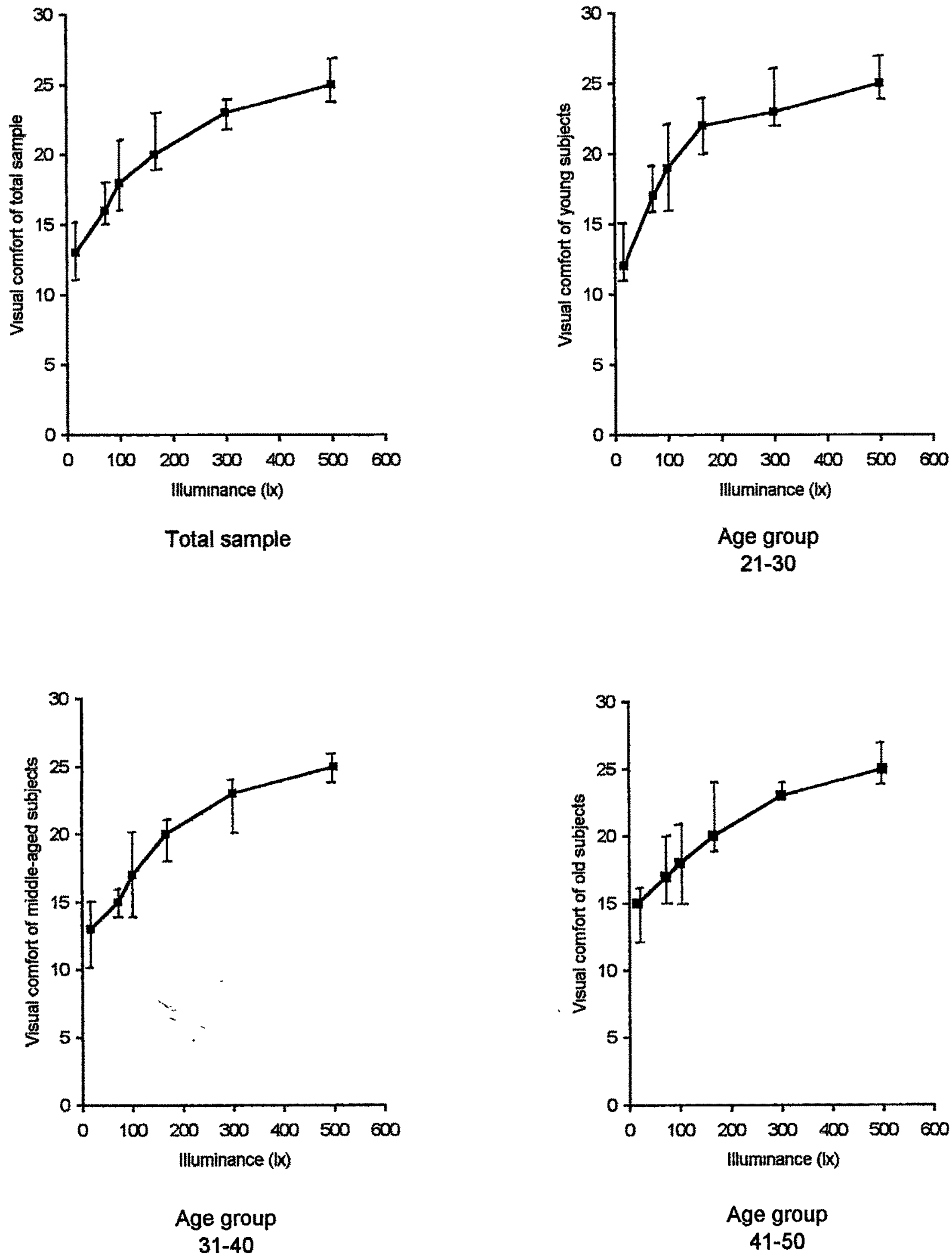


Figure 20: Median and interquartile ratings of perceived level of visual comfort of total sample and of subjects in different age groups under varying illuminances.

Since these subjects were accustomed to low illuminances and their requirements were fulfilled under the same, their PLoVC under low illuminances in the simulated kitchen was relatively higher and they probably found higher illuminances to be extravagant.

5.0 HYPOTHESES TESTING

This section deals with the observations made in relation to testing of hypotheses pertaining to the data gathered through the laboratory experimentations carried out in the simulated kitchen. The level of visual performance of subjects was ascertained on visual acuity test comprising of landolt's rings of selected sizes. To test the hypothesis, the performance score earned on one test object each from each of the four categories by visual size (angle), namely ; large (test object 'A') , medium (test object 'D'), medium-small (test object 'F') and small (test object 'G') against each of the three selected brightness contrasts under each of the six selected illuminances (LoP I) were utilised. The sum of level of visual performance on large, medium, medium-small and small test objects reflected the overall LoP I (OLoP I). The scores earned by the subjects on brownness discrimination test under the selected illuminances is identified as LoP II.

What is the combined effect of different illuminances and background contrasts on LoP I of subjects of varying age groups ? To what extent the differences in mean LoP I of subjects against each of the brightness contrast could be explained by selected illuminances ? To what extent the differences in mean LoPI of the subjects under illuminance of 500 lx and each of the other illuminance could be explained by the effect of brightness contrasts between the test object and the background ? What is the interactive effect of age and brightness contrasts on mean LoP I under different illuminances ? What is the interactive effect of age and illuminance on mean LoP I against different brightness contrasts ? What is the effect of the selected illuminances on the level of visual performance of the subjects on brownness discrimination test (LoP II) ? Were there any differences in the perceived level of visual comfort experienced by the subjects under varying illuminances ? These were some of the questions that directed the process of analysis of data generated through laboratory estimations.

To test the hypotheses statistically, null hypotheses were formulated. The 'repeated measures MANOVA' was computed for the entire experimental data on the level of visual performance with regard to the selected variables. Non parametric tests like Friedman's test and Mann Whitney test were applied to test the hypothesis on perceived level of visual comfort (PLoVC) and the selected variables under study. The findings and discussions pertaining to Hypothesis B I and B II are presented first followed by that of Hypothesis B III.

Findings and Discussion in Relation to Hypotheses B I and B II

Null hypotheses were framed for the purpose of testing the hypotheses formulated for the study. Hypothesis B I states that there exists a difference in the level of visual performance of subjects of different age groups on standard visual acuity test i.e., landolt's ring test against different brightness contrasts under varying illuminances in the simulated kitchen. Hypothesis B II states that there exists a difference in the level of visual performance of subjects on brownness discrimination test under varying illuminances in the simulated kitchen. Null hypotheses (H_0B I and H_0B II) were framed as presented below :

H_0B I : There exists no difference in the level of visual performance (LoP I) of subjects of different age groups on standard visual acuity test i.e, landolt's ring test against different brightness contrasts under varying illuminances in the simulated kitchen.

H_0B II : There exists no difference in the level of visual performance of subjects on brownness discrimination test (LoP II) under varying illuminances in the simulated kitchen.

Sub hypotheses $H_0B\ I_1$ to $H_0B\ I_5$ were framed for H_0B I for application of repeated measures MANOVA as presented in the ensuing pages. The presentation of findings on $H_0B\ I_1$ to $H_0B\ I_5$, is followed by that of H_0B II.

H_0BI_1 : There exists no difference in the level of visual performance of subjects on visual acuity test against different brightness contrasts under varying illuminances by their age.

The mean age of subjects in young, middle and old age groups were 24.62 years, 35.46 years and 45.62 years respectively (Table 26, Appendix VI). The mean scores of the subjects on observation power of the three age groups were more on less similar (5.46, 5.69 and 5.46 for subjects in young, middle and old age groups respectively). However, the mean scores on rate of visual perception were also found to be relatively low in old subjects (27.85) as compared to the subjects in young and middle age groups (29.23 and 26.69 ** respectively).

To test the above hypothesis 'repeated measures MANOVA' was computed on the overall level of visual performance(OLoP $I_{L\ BC}$) and level of visual performances of the subjects on each of the four selected test objects against all brigntness contrast under all illuminances, namely, large (LoP $I_{L\ BC\text{-}L}$), medium (LoP $I_{L\ BC\text{-}M}$), medium-small (LoP $I_{L.BC\text{-}MS}$) and small (LoP $I_{L.BC\text{-}S}$). The computed 'F' values revealed a significant difference at 0.01 level in the OLoP $I_{L\ BC}$ and LoP $I_{L.BC\text{-}L}$, through to LoP $I_{L\ BC\text{-}S}$ respectively of the subjects by their age for all the four test objects (Table 34, Appendix VI). The mean scores on OLoP $I_{L\ BC}$ of old subjects differed significantly at 0.01 level from those of subjects of young and in middle age groups as evidenced by the significant calculated 't' values (Table 51). Comparison of mean scores revealed that subjects in old age group were significantly different from those in (i) young (.01 level) (ii) middle (.05 level) age group in their LoP $I_{L\ BC\text{-}L}$. Significant differences at .01 level were observed between old subjects and those in (i) young and (ii) middle age groups in their LoP $I_{L.BC\text{-}M}$,, LoP $I_{L.BC\text{-}MS}$ and LoP $I_{L.BC\text{-}S}$. The sub-null hypothesis was thus rejected.

It was found that there was a successive decline in the mean scores on OLoP $I_{L\ BC}$ and LoP $I_{L.BC\text{-}L}$ through to LoP $I_{L.BC\text{-}S}$ from young to old age groups due to combined effect of different brightness contrasts and varying illuminances. The drop in the OLoP $I_{L\ BC}$ was not statistically significant between the subjects in young age group and those in middle age group, but was found to be statistically significant between the subjects in each of the two

Table 51 : Difference between mean scores on the level of visual performance of subjects on visual acuity test against different brightness contrasts under varying illuminances by their age

Group	Age Category	N	OLoP $I_{L.BC}$ Means		LoP $I_{L.BC-L}$ Means		LoP $I_{L.BC-M}$ Means		LoP $I_{L.BC-MS}$ Means		LoP $I_{L.BC-S}$ Means	
1	21-30 years	13	1961.23		552.23		529.85		473.46		405.69	
2	31-40 years	13	1879.38		546.69		524.15		442.31		366.23	
3	41-50 years	13	1425.00		513.77		441.62		292.85		176.77	
Mean	Contrast		Mean difference	't' value	Mean difference	't' value	Mean difference	't' value	Mean difference	't' value	Mean difference	't' value
1	2		81.85	0.81	5.54	0.43	5.69	0.26	31.15	0.84	39.46	1.09
2	3		454.38	4.52**	32.92	2.57*	82.54	3.82**	149.46	4.04**	189.46	5.24**
1	3		536.23	5.33**	38.46	2.99**	88.23	4.09**	180.62	4.88**	228.92	6.33**

* Significant at .05 level

** Significant at .01 level

younger age groups and those in old age group. The combined effect of varying illuminances and brightness contrasts was the most adverse on the LoP I of old subjects as compared to those of subjects in young and middle age groups. The old subjects, in contrast to the subjects in two younger age groups, were observed to have relatively low mean LoP $I_{L.BC\text{-}L}$ through to LoP $I_{L.BC\text{-}S}$ which contributed to their low mean OLoP $I_{L\ BC}$; the differences being strikingly high with reference to their performances on medium small and small landolt's rings of 1' 29" and 1' 8" arc respectively. A comparative analysis of the mean scores of the two younger age groups and old age group revealed that the drop in the mean visual performance of old subjects on medium-small test objects against BC.2 and BC.3 under illuminance of 166 lx through to 72 lx was by a little more than 40 per cent in each of the illuminances, while that under 17 lx was almost double (Table 31,32 and 33 , Appendix VI). With regard to the small test objects, the relative fall in the mean visual performance of the old subjects against BC.1 in comparison to those of the subjects in the younger age groups under each of the illuminances from 500 lx through to 72 lx ranged between 30 to 50 per cent and that under illuminance of 17 lx was between 80 to 90 per cent. The drop in mean visual performance of old subjects on small test objects against BC.2 and BC.3 was still more pronounced than those of the younger two groups under all the illuminances studied. These observations are in line with those of Weston (1949), Blackwell (1962 and 1969), Hopkinson and Collins (1970) and Smith and Rea (1980). The investigators provided experimental evidences that speed and accuracy in discriminating small detail declines with advancing age.

With advancing age the maximum pupil aperture decreases leading to a decline in power of accommodation of the eye (both in terms of speed and precision) and the proportion of light lost by absorption and scatter in the eye increases. The latter could be due to yellowing of the lens and changes in the occular media, and probably some loss of retinal transmission and sensitivity. It is reasonable to assume that the central parts of the visual system are also affected by age and thus it becomes more difficult to discriminate fine detail in close tasks. According to Krueger and Hessen , these functions show a marked decrease from about the age of 40. However, the defects in the eye caused by aging factor to a large extent can be corrected by use of appropriate lens, which was done in the present investigation. Yet, drastic differences were observed in the mean LoP $\acute{I}_{L.BC}$ between the old subjects and subjects in two younger age groups.

The differences in the speed of the subjects can be identified as another important attribute to account for the differences in OLoP $I_{L\ BC}$ between the old subjects and those in younger age groups. Speed of perception i.e., the time interval that elapses between the appearance of a visual information and its conscious perception in the brain, as well as the speed of actual doing of the visual task might have been slower in case of subjects in the old group. This reasoning can be substantiated by the relatively low mean scores earned by the old subjects on the test of rate of visual perception as compared to that of subjects in young and middle age groups (Table 30, Appendix IV). The difference could be further attributed to the concentration and alertness level of the subjects, which might have been relatively lower amongst the old subjects in contrast to the younger subjects.

$H_oBI_{1\,2}$: There is no difference in the level of visual performance of subjects on visual acuity test against different brightness contrasts by varying illuminances.

The recommended illuminances for domestic kitchens, with 500 lx at the work areas and 300 lx for general lighting (Phil ips Lighting Manual, 1993), was one of the six levels of illuminances simulated for experimental purpose. Illuminances of 300 lx and 100 lx at the work areas with corresponding illuminance of 180 lx and 60 lx for general lighting were also created, maintaining a similar illuminance ratio of 5:3 between task area and surround. In addition, illuminance levels observed in the best lit and worst lit kitchens from amongst the field kitchens in the inter quartile range by area were created. The best lit kitchen had two differential levels of illuminance, namely, 166 lx and 72 lx on its work areas along the platform and 57 lx for general lighting while the worst lit kitchen had a corresponding average illuminance of 17 lx.

The computed 'repeated measure MANOVA' revealed statistically significant differences at .01 level in the overall level of visual performance (OLoP I_{BC}) and level of visual performance of the subjects on test object of visual sizes large (LoP I_{BC-L}), medium (LoP I_{BC-M}), medium-small (LoP I_{BC-MS}) and small (LoP I_{BC-S}) by varying illuminances (Table 35, Appendix VI). The computed 't' values indicated that the mean OLoP I_{BC} of the subjects under illuminance of 500 lx was significantly different at .01 level than those under illuminance of (i) 166 lx (ii) 100 lx (iii) 72 lx and (iv) 17 lx. Significant differences at .01 level were observed in the mean LoP I_{BC-L} through to LoP I_{BC-s} of the subjects between illuminances of 500 lx and (i) 100 lx (ii) 72 lx and (iii) 17 lx. In addition the

Table 52 : Difference between mean scores on the level of visual performance of subjects on visual acuity test under varying illuminances by brightness contrasts

Group	Brightness contrast	N	OLoP I_L		LoP I_{L-L}		LoP I_{L-M}		LoP I_{L-MS}		LoP I_{L-S}	
			Means		Means		Means		Means		Means	
1	BC.1	39	618.72		181.82		171.38		147.28		118.23	
2	BC.2	39	568.64		175.51		161.15		129.10		102.87	
3	BC.3	39	567.85		180.23		166.00		126.49		95.13	
Mean	Contrast		Mean difference	't' value	Mean difference	't' value	Mean difference	't' value	Mean difference	't' value	Mean difference	't' value
1	2		50.08	8.31**	6.31	5.69**	10.23	5.21**	18.18	8.40**	15.36	5.60**
2	3		0.79	0.13	4.72	3.45**	4.85	3.44**	2.62	0.45	7.74	2.33*
1	3		50.87	10.21**	1.59	1.53	5.38	3.09**	20.79	9.85**	23.10	8.18**

* Significant at .05 level

** Significant at .01 level

mean LoP $I_{BC\text{-}MS}$ and LoP $I_{BC\text{-}S}$ of the subjects were also found to be significantly different (.01 level) when mean differences were compared between illuminance of 500 lx and 166 lx (Table 52). Thus on the strength of the computed 't' values the sub-null hypothesis was rejected.

It was found that the mean scores on OLoP I_{BC}, LoP $I_{BC\text{-}MS}$ and LoP $I_{BC\text{-}S}$ decreased with each successive decline in illuminance (500 lx through to 17 lx) and the differences were found to widen from the highest to the lowest illuminance. The mean level of performance of subjects on large (LoP $I_{BC\text{-}L}$) and medium size (LoP $I_{BC\text{-}M}$) objects under illuminance of 300 lx were slightly more than those under other illuminances. (Table31,32 and 33, Appendix VI). The LoP $I_{BC\text{-}L}$ of subjects did not reveal a consistent pattern when the same under illuminance of 166 lx to 17 lx were compared. The statistical analysis of data revealed that there were no significant differences in the mean OLoP I_{BC} and LoP $I_{BC\text{-}L}$ through to LoP $I_{BC\text{-}S}$ of the subjects under illuminance of 500 lx and that under 300 lx, indicating that subjects had performed equally well under these illuminances. Also the mean LoP $I_{BC\text{-}L}$ and LoP $I_{BC\text{-}M}$ of the subjects did not show any significant differences under illuminance of 500 lx and 166 lx. The mean cumulative result of the OLoP I_{BC} against the three background contrasts seemed to be significantly different between illuminance of 500 lx and 166 lx as well as the other lower illuminances. The sharp fall in the visual performance of the subjects on landolt's rings of medium-small and small size against each of the brightness contrasts under the illuminances of 100 lx, 72 lx and 17 lx could have contributed to relatively poor OLoP I_{BC} under lower illuminances. The visual performance of the subjects against BC.2 and BC.3 was noticeably low under lower illuminances. The findings of the present study that the OLoP I_{BC} improves with increase in illuminance is in agreement with that of earlier researches wherein the effect of illuminances on performance of visual tasks have been established (Luckesh, 1948 ; Weston, 1949 ; Kuntz and Sleight, 1949 ; Tinker, 1949 ; Gilbert and Hopkinson, 1949 ; McCormick and Niven, 1985 ; Blackwell, 1959 and Maitreya, 1977).

The findings of the present study has relevance for the kitchen activities. In a kitchen variety of tasks are performed ranging from ones requiring high visual acuity to those requiring low visual acuity. For example, at the sink area one may wash intricate cut-work glasses with fine design and crevices or blades of a mixer or small kitchen tools for chopping and churning, or wash green leafy vegetables like fenugreek, which lay heavy visual demands on the worker. On the other hand, activities like cleaning of 'thali' or water glasses may not require high visual acuity. Similarly, at the pre-preparation area, activities like cleaning of cumin seeds, mustard seeds, sesame, 'ajwain' or reading of recipie and instructions on food packets or vegetable carving or icing of cake or measuring and evaluating ingredients are fine tasks and require high visual acuity while tasks like kneading dough or rolling 'chappati' or cutting potatoes can relatively be performed with visual ease. As evident from the findings of the present study, activities that do not have minute details can easily be performed under an illuminance of 166 lx. However when it comes to fine tasks where high visual acuity is required, a minimum illuminance of 300 lx is required which is less than the recommended value (Philips Lighting Manual, 1993).

Considering the visual performance of the subjects, the results obtained do not offer strong support for recommended illuminance of 500 lx. The illuminances in field kitchens were abysmally low and the laboratory experimentation has revealed that the performance level under 300 lx were comparable with those under recommended value of 500 lx in reference to all visual sizes of tasks. In other words, it implies that the worker's performance in the kitchen would be adversely affected in case work is done under illuminances lower than 300 lx, especially, when fine tasks or tasks with minute details are done. The exceptionally low illuminances in the residential kitchens can have detrimental effects not only on the quantity of tasks performed out also on the quality of tasks accomplished as well as on the health, comfort and safety of the worker.

$H_0BI_{1.3}$: There exists no difference in the overall level of visual performance of subjects of different age groups on visual acuity test under varying illuminances (OLoP I_L), by brightness contrast.

The three brightness contrasts for test objects against its backgrounds, were created keeping in mind the brightness contrasts generally found in kitchens, where white marble platform or light to dark grey cemented platform or white ceramic plates or light grey steel utensils form the backgrounds against which various tasks are carried out. The main effect of brightness contrasts was studied by pooling the data of all the subjects under all the different illuminances.

The computed 'repeated measures MANOVA' revealed a significant difference at 0.01 level in the overall level of visual performance OLoP I_L as well as in the level of visual performance on each of the different sizes of test objects namely large (LoP I_{L-L}), medium (LoP I_{L-M}), medium small (LoP I_{L-MS}) and small (LoP I_{L-S}) of the subjects by brightness contrasts (Table36, Appendix VI). On application of 't' test on the performance scores, it was found that the OLoP I_L of the subjects against BC.1 was significantly different at .01 level from that against (i) BC.2 and (ii) BC.3. Subjects were found to be significantly different (.01 level) in their LoP I_{L-L} against BC.1 and BC.2. The LoP I_{L-M}, LoP I_{L-MS} and LoP I_{L-S} of the subjects against BC.1 differed significantly at .01 level from those against (i) BC.2 and (ii) BC.3. Significant differences were also observed in the LoP I_{L-L} (.01 level), LoP I_{L-M} (.01 level) and LoP I_{L-S} (.05 level) of subjects when their performances between BC.2 and BC.3 were compared on large, medium and small size test objects (Table 53).

On the strength of the above findings the sub-null hypothesis was rejected.

The mean scores earned by the subjects on OLoP I_L and LoP I_{L-L} through to LoP I_{L-S} prove beyond doubt the effect of brightness contrast of the highest order (BC=0.89) on their performance as evidenced through relatively higher OLoP I_L as well as LoP I_{L-L} through to LoP I_{L-S} in comparison to those against BC.2 (0.61) and BC.3 (0.57). However, the effect of moderate (BC.2) and low (BC.3) brightness contrasts was not consistent as evidenced through the irregular performances of subjects on landolt's ring test of the large and medium size, and medium small and small sizes. In general, it was found that the LoP I_{L-L} and LoP I_{L-M} of the subjects against BC.3

Table 53 : Difference between mean scores on the level of visual performance of subjects on visual acuity test under varying illuminance by brightness contrasts

Group	Illuminance (lx)	N	OLoP I_{BC}		LoP I_{BC-L}		LoP I_{BC-M}		LoP I_{BC-MS}		LoP I_{BC-S}	
			Means		Means		Means		Means		Means	
1	500	39	327.72		91.67		87.77		78.56		69.72	
2	300	39	326.41		91.77		88.54		77.46		68.64	
3	166	39	313.00		90.92		87.44		72.49		62.15	
4	100	39	289.69		87.92		81.23		65.87		54.67	
5	72	39	268.49		89.13		80.31		64.59		34.46	
6	17	39	229.90		86.15		73.26		43.90		26.59	
Mean	Contrast		Mean difference	't' value	Mean difference	't' value	Mean difference	't' value	Mean difference	't' value	Mean difference	't' value
1	2		1.31	0.30	- 0.10	0.13	- 0.77	0.56	1.10	0.68	1.08	0.51
1	3		14.72	3.15**	0.74	0.79	0.33	0.22	6.08	3.75**	7.56	3.30**
1	4		38.03	5.77**	3.74	4.17**	6.54	4.07**	12.69	5.01**	15.05	4.88**
1	5		59.23	12.62**	2.54	3.10**	7.46	4.02**	13.97	7.50**	35.26	13.45**
1	6		97.82	15.01**	5.51	4.62**	14.51	5.89**	34.67	11.63**	43.13	12.66**

* Significant at .05 level

** Significant at .01 level

were relatively higher as compared to those against BC.2, while a reverse trend was observed in case of LoP I_{L-MS} and LoP I_{L-S}. However, the mean scores on OLoP I_L against BC.2 and BC.3 were found to be more or less comparable.

The analysis of data revealed that the OLoP I_L of the subjects was significantly high against BC.1 as compared to that against BC.2 and BC.3, while the differences between the OLoP I_L against BC.2 and BC.3 were not found significant. The mean scores on visual performances of the subjects on each of the four selected test objects against BC.1 under each of the six illuminances were distinctly high as compared to the same against BC.2 and BC.3. The relative fall in visual performance of subjects against BC.2 and BC.3 were found to be particularly marked at lower levels of illuminances, and for minute test objects (medium-small and small size of landolt's rings). The fall in visual performance of the subjects on medium-small test object against BC.2 and BC.3, as compared to that against BC.1 ranged between 10 per cent under illuminance of 500 lx upto 60 per cent under 17 lx, while the fall in visual performance on small test object against BC.2 and BC.3 ranged between 20 per cent under illuminance of 500 lx upto 100 per cent under 17 lx. The cumulative effect of excessively low visual performance on medium-small and small test objects under lower illuminances might have contributed to low OLoP I_L against BC.2 and BC.3. The effects of brightness contrasts between the work object and its background on the visual performances has been studied experimentally by a number of investigators. Moreover, the interaction of brightness contrast with size of the detail and illuminance has also been explored (Weston, 1943 ; Gilbert and Hopkinson, 1949 ; Colombo and Kirschbaum, 1990). The findings of the present investigation are in line with the same.

An analysis of the physiology of reading reveals that for rapid and good recognition of character, it is important that the characters are identifiable and distinctive. According to Grandjean (1988) para foveal word recognition is critically dependent on character contrast. The lower the contrast, the narrower is the visual reading field and the 'lower' therefore, the readability. Weston (1943) studied the effects of brightness contrasts on performance and found that increase of illumination cannot always be a complete compensation for poor contrast, often the effect of increase in brightness contrast in work outweighs by far the effect of any reasonably increase of illumination.

$H_0BI_{1\cdot4}$: There is no difference in the level of visual performance of subjects on visual acuity test against different brightness contrasts by the interaction between their age and illuminances.

The significance in the mean differences in visual performance of subjects due to the interaction of illuminances and age of subjects was statistically tested by computing MANOVA. Significant difference at .01 level was found in the mean LoP $I_{BC\text{-}M}$ and LoP $I_{BC\text{-}MS}$ due to the interactive effect of illuminances and age of subjects (Table 37, Appendix VI). The mean differences were not found significant with reference to the OLoP I_{BC}, LoP $I_{BC\text{-}L}$ and LoP $I_{BC\text{-}S}$. The computed 't' values on the mean differences in the LoP $I_{BC\text{-}M}$ and LoP $I_{BC\text{-}MS}$ under illuminances of 500 lx and 17 lx were found to be significant at .01 level between subjects in old age group and those in (i) young and (ii) middle age groups. The mean differences in LoP $I_{BC\text{-}M}$ under illuminances of 500 lx and 72 lx were found significantly different at 0.5 level between subjects in old age group

Table 54 : Difference between mean scores on the level of visual performance of subjects on visual acuity test against different brightness contrasts by interaction between age and illuminances

Group	Age Category	N	LoP I_{BC-M}						LoP I_{BC-MS}					
			500 lx and 72 lx			500 lx and 17 lx			500 lx and 166 lx			500 lx and 17 lx		
			Mean 500 lx	Mean 72 lx	Mean difference	Mean 500 lx	Mean 17 lx	Mean difference	Mean 500 lx	Mean 166 lx	Mean difference	Mean 500 lx	Mean 17 lx	Mean difference
1	21-30 years	13	91.92	87.69	4.23	91.92	82.62	9 3	86 46	86 31	0.15	86.46	62.62	23.84
2	31-40 years	13	90.23	86.31	3.92	90.23	81.85	8.38	83.62	78.85	4.77	83.62	53.92	29.70
3	41-50 years	13	81.15	66.92	14.23	81.15	55.31	25.84	65.62	52.31	13.31	65.62	15.15	50.47
Mean	Contrast		Mean Diff.	't' value		Mean Diff.	't' value		Mean Diff.	't' value		Mean Diff.	't' value	
1	2		0.31	0.07		0.92	0.15		4.62	1.16		5.85	0.80	
2	3		10.31	2.27*		17.46	2.90**		8.54	2.15*		20.77	2.85**	
1	3		10.00	2 20*		16.54	2.74**		13.15	3.32**		26.62	3.65**	

* Significant at .05 level

** Significant at .01 level

and those in (i) young and (ii) middle age groups. Also significant mean differences in LoP I_{BC-MS} under illuminance of 500 lx and 166 lx were found between subjects in old age group and those in (i) young (0.1 level) and (ii) middle (.05 level) age groups (Table 5). On the strength of the computed 't' values, the sub-null hypothesis was partially accepted.

A progressive decline in the mean differences in LoP I_{BC-M} and LoP I_{BC-MS} between illuminances of 500 lx and 17 lx and in LoP I_{BC-MS} between illuminance of 500 lx and 166 lx was observed for subjects in young through to old age group. The mean difference in LoP I_{BC-M} between illuminance of 500 lx and 72 lx of subjects in middle age group was relatively low as compared to that of subjects in young age group. These mean differences were found to be distinctly high in the old age group as compared to the two younger age groups. The drop in the mean visual performance on medium size test objects under illuminance of 17 lx, in contrast to that under 500 lx, was by 5 to 6 per cent against BC.1 and BC.2 and about 16 per cent against BC.3 in the two younger age groups while the fall was by 25 per cent and 35 per cent against BC.1 and BC.2 respectively in the older age group (Table 31,32 and 33, Appendix VI). With reference to the medium-small test object, the drop in mean visual performance of subjects in two younger age groups was by 35 per cent against BC.1 and between 50 to 70 per cent against BC.2 and BC.3, while the performance of older subjects tripped by 85 per cent against BC.1 and by 98 per cent against BC.2 and BC.3.

Thus it can be concluded that the relationship between illuminance and visual performance changes as the age of the worker increases. The effects of age upon the visual system tends to reduce the visual efficiency of the worker. However, these effects can be partly offset by better illuminance. As age advances, a given increment of illuminance, becomes relatively more effective and brings about a greater percentage improvement of visual performance. Similar observations were reported by Fortuin (1948), Bodmann (1962) and Blackwell (1969).

$H_0BI_{1.5}$: There is no difference in level of visual performance of subjects on visual acuity test with selected test objects under varying illuminances by the interaction between their age and brightness contrasts.

To test the above hypothesis 'repeated measures MANOVA' was carried out to assess significance in the mean differences in the visual performance of subjects due to interaction of brightness contrasts and age of subjects. Significant difference at .01 level was found in the mean OLoP I_L, LoP I_{L-M} and LoP I_{L-MS} due to the interaction between brightness contrasts and age of subjects, while such mean differences were not found significant with regard to LoP I_{L-L} and LoP I_{L-S} (Table 38, Appendix VI). The computed 't' values indicated that the mean differences between the OLoP I_L against BC.1 and that against BC.3 of the subjects in old age group were significantly different from corresponding values of the subjects in (i) young (.01 level) and (ii) middle (.05 level) age groups. The computed 't' values of mean differences in the LoP I_{L-M} and LoP I_{L-MS} against BC.1 and BC.3 and mean difference in LoP I_{L-M} against BC.2 and BC.3 difference in between old and young subjects were found to be significant at 0.01 level. Similarly, the mean differences in LoP I_{L-MS} against BC.1 and BC.3 and mean difference in LoP I_{L-M} against BC.2 and BC.3 between subjects of middle and old age groups were significantly different at 0.05 and 0.01 levels respectively, as evidenced through the 't' values. Significant difference at .01 level

Table 55 : Difference between mean scores on the level of visual performance of subjects on visual acuity test under varying illuminances by interaction between age and brightness contrasts

Group	Age Category	N	OLoP I_L			LoP I_{L-M}						LoP I_{L-MS}					
			BC.1 and BC 3			BC.1 and BC.3			BC.2 and BC.3			BC.1 and BC.3			BC.1 and BC.2		
			Mean BC.1	Mean BC.3	Mean diff. in BC 1 & BC.3	Mean BC.1	Mean BC 3	Mean diff. in BC.1 & BC.3	Mean BC.2	Mean BC.3	Mean diff. in BC.2 & BC.3	Mean BC.1	Mean BC.3	Mean diff. in BC.1 & BC.3	Mean BC.1	Mean BC.2	Mean diff. in BC.1 & BC.2
1	21-30 years	13	672.69	647.62	25 07	179.00	180.77	- 1.77	170.08	180.77	10.69	164.15	153.62	10.53	164.15	155.69	8.46
2	31-40 years	13	662.00	613.23	48.77	180.08	176.46	3.62	167.62	176.46	8.84	161.00	140.92	20.08	161.00	140.38	20.62
3	41-50 years	13	521.46	442.69	78.77	155.08	140.77	- 14.31	145.77	140 77	5.00	116.69	84.92	31.77	116.69	91.23	25.46
Mean	Contrast		Mean Diff.	't' value		Mean Diff.	't' value		Mean Diff.	't' value		Mean Diff.	't' value		Mean Diff.	't' value	
1	2		23.69	1.94		5.38	1.26		1 85	0.54		9.54	1.84		12.15	2.29*	
2	3		30.00	2.46*		10.69	2.50		13.85	4.01**		11.69	2.26*		4.85	0.91	
1	3		53 69	4.40**		16.08	3.76**		15.69	4.55**		21.23	4.10**		17 00	3.21**	

* Significant at 05 level

** Significant at .01 level

was found between the old subjects and young subjects in their mean differences that existed between LoP I_{L-M} against BC.2 and that against BC.3. The computed 't' values were found to be significant at 0.01 level, when the mean differences in the LoP I_{L-MS} against BC.1 and BC.2 of subjects of young and old groups were compared (Table 55). Thus, the null hypotheses was partially accepted.

Analysis of data revealed that the differences in mean scores on the overall level of visual performance (OLoP I_L) of the subjects were prominent between BC.1 and BC.3 and there was a successive increase in the differences in the mean scores from young to old age groups. The effects of differences in the brightness contrast between the test object and the background on the OLoP I_L appeared to increase from young to old category of subjects and the same was observed to be more profound in the subjects in old age group as compared to those in the two younger age groups. A higher OLoP I_L on test objects against high brightness contrast was observed in the subjects of all age groups. Blackwell (1969) found that the average performance on contrast discrimination of observers between 62 to 66 years of age required seven times more light than the average performance of the 17 to 29 years old. The decreased visual function with age creates difficulty in the ability to focus on objects that are not projected distinctly and may lead to eye strain. This holds special relevance for minute test objects. The findings of the study, therefore, imply that careful attention must be paid to the design of visual tasks and its performance with special reference to the brightness contrast between the task and its back ground in order to take account of the variations in visual abilities among different age groups. The use of appropriate brightness contrast can be a useful aid for visual search that can help to locate the required information and items quickly.

H_0BI_2 : There is no difference in the level of visual performance of subjects on brownness discrimination test (LoP II) under varying illuminances.

The mean scores on LoP II of subjects revealed more or less comparable values ranging from 25.6 to 27.0 under illuminance of 500 lx, 300 lx and 166 lx. Thereafter, there was a successive decline in the mean scores under lower illuminances. The mean scores on the LoP II amongst the subjects in the three age groups ranged from 24.8 to 26.0 under illuminance of 100 lx and 72 lx. The mean scores under illuminance of 17 lx were 22.9, 21.9 and 21.5 of the subjects in young, middle and old age group respectively (Figure 19).

To test the above hypothesis 'repeated measures MANOVA' was computed. The difference in the LoP II amongst the three age groups was not significant (Table 39, Appendix VI). The differences in the LoP II due to the interaction of age and illuminance were also not found significant. However, significant differences at 0.01 level were observed in the LoP II with regard to varying illuminances (Table 40, Appendix VI). The computed 't' values revealed that the LoP II of the subjects test under illuminance of 500 lx differed significantly at .01 level from that under illuminance of (i) 100 lx (ii) 72 lx and (iii) 17 lx (Table 56). Thus the null hypothesis was partially accepted.

Table 56 : Difference between mean scores on LoP II under varying illuminances

Group	Illuminances (lx)	N	Mean
1	500	39	26.92
2	300	39	26.49
3	166	39	26.64
4	100	39	25.62
5	72	39	25.05
6	17	39	22.10

Mean	Contrast	Mean differences	't' value	Level of significance
1	2	0.44	1.30	n.s.
1	3	0.28	0.96	n.s.
1	4	1.31	4.08	.01
1	5	1.87	6.26	.01
1	6	4.82	13.54	.01

The findings offer strong support to the fact that ability to discriminate different degrees of brownness is adversely affected under low illuminances. The degree of browness is an important indicator to assess the stage of cooking attained while frying and roasting a variety of items like onions, semolina, chopped dried nuts and so on and, frying. It the items get over-browned, then the aroma and the taste of the food deviates from the desirable state. As found in the study, illuminances upto 166 lx permits accuracy in identification of brownness as that achieved under 500 lx. The kitchen lighting below 166 lx would not be appropriate for checking the degree of brownness as accurately as that would be possible under 500 lx with naked eye especially in the case of food items comparable to semolina foods. In other words, it implies that illuminance of 166 lx would provide an adequate visual environment to clearly discriminate the varying degrees of brownness for cooking such items by roasting or frying methods in the process.

Findings and Discussion in relation to Hypothesis B II

With reference to Hypothesis B II which states that there exists a difference in the perceived level of visual comfort (PLoVC) of the subjects under varying illuminances, null hypothesis with sub hypotheses as given below were framed.

H_0B II : There exists no difference in the perceived level of visual comfort (PLoVC) of the subjects of different age groups under varying illuminances.

H_0B II_1 : There exists no difference in the perceived level of visual comfort (PLoVC) of the subjects under varying illuminances by their age.

The mean as well as the median values on PLoVC under the six selected illuminances revealed negligible differences amongst the three age groups (Fig 20). The Mann – Whitney U test was applied to test the differences in PLoVC between each pair of the three age groups under each illuminance. The tests showed that there were no significant differences in the rank ordered PLoVC between the age groups under any of the six selected illuminance. Thus the null hypothesis was accepted.

H_0BII_2 : There is no difference in the perceived level of visual comfort (PLoVC) of the subjects under illuminances.

A successive decline in the mean and median values on PLoVC was observed with each drop in illuminance from 500 lx through to 17 lx. The drop in the scores on PLoVC was noticeably high under illuminance of 17 lx as compared to illuminance of 500 lx. To test the above hypothesis, the Friedman two-way analysis of variance by ranks was computed. The Friedman test revealed statistically significant differences (0.01 level) in ratings on PLoVC under the six selected illuminances (Table 57).

Table 57 : Mean ranks on PLoVC under varying illuminances

Illuminance (lx)	Mean Rank			
	Young age group	Middle age group	Old age group	Total
500	5.46	5.73	5.69	5.63
300	4.92	5.00	4.65	4.86
166	3.85	3.65	4.12	3.87
100	3.23	2.77	2.81	2.94
72	2.50	2.23	2.27	2.33
17	1.04	1.62	1.46	1.37
Total	13	13	13	39
Chi-square	48.75	48.09	47.04	141.77
Level of significance	.01	.01	.01	.01

The mean ranks on PLoVC of the subjects were found to decrease with decreasing illuminances. The finding implied that the subjective judgements of subjects regarding adequacy and brightness of illuminance, pleasantness and comfort features of lighting varied with change in illuminance. The fact that the total score on subjective assessments of the subjects became more and more less with every decrease in illuminance, stress that the lighting for working interiors should be based on visual performance as well as visual comfort parameters. The degree of visual satisfaction in terms of comfort and pleasantness created by the lighting is an important, additional design consideration.

6.0 RECOMMENDED ILLUMINANCES AND LIGHTING (LAMP) INSTALLATIONS FOR RESIDENTIAL KITCHENS OF AVERAGE INDIAN FAMILY

Lighting is an important element of the interior of kitchen, and good lighting is vital to the efficient and smooth functioning of a kitchen. An appropriately lit kitchen is imperative for safety purposes and can go a long way in helping prevent injuries. Since there are many tasks performed in the kitchen, lighting should primarily be functional, and then decorative. It is essential that all the areas in a kitchen are equally and adequately lighted. The light should reach all surfaces, not only the horizontal flat working surfaces, but also the vertical areas to facilitate the task of finding things in cupboards.

A kitchen consists of a series of work stations for mixing, cleaning, cooking, and at times even eating. Each needs its own lighting. At most work stations, the action takes place at the counter top, so it is critical to light the counters well. The light at the work station should be intense, because it is necessary to discern details of the food being cleaned or cooked. Thus, it is recommended to have two types of electric lighting for a kitchen : general and specific task lighting. Direct lighting over the work surface helps to ensure proper visibility and safety of the worker while working in the kitchen. Also, lighting each work counter erases the worker's shadow while at work. A carefully worked out balance between general and task lighting provides a pleasant, glare - free general atmosphere, and direct, shadow-free illumination over the work stations. The ratio of 5:3 in illuminance is recommended between task and general lighting to ensure illuminance uniformity, comfortable shadow free lighting and balance between the two.

In the kitchen where work goes on for many hours each day, should be made use of energy saving lamps that emit less heat and are comfortable to work with to the fullest. A low-wattage lighting, placed over a work centre can be a considerable saving over lighting the whole kitchen. Incandescent lamps are less expensive to buy and its life is not adversely affected by switching on and off frequently in contrast to fluorescent and CFL or Trulite lamps. However, the average life of incandescent lamp is of 1/7 th of fluorescent and CFL lamps and thus needs more frequent replacement. Moreover, incandescent lamps 'die out' unpredictably any time. In terms of electric power consumption, these are very costly to the user as well as to the environment. Therefore, fluorescent lighting is more effective and much cheaper in the long run than ordinary bulbs. A liberal use of fluorescent lamps in the kitchen not only costs less on energy consumption but also provides adequate bright light.

The lighting research in the latter half of 20^{th} century has presented still more energy efficient lamps like fluorescent trulite/slimline lamps and compact fluorescent lamps (CFL). The best option from the perspective of electrical energy conservation without compromising on efficient lighting can be provided by use of CFL or other energy saving lamps. Dasgupta (1997) described CFL as an eco-friendly option for a tropical country like India, having benefits of 75-80 per cent saving in electrical energy for the same light output, more durability, lesser heat emission and different colour appearance (warm or cool).

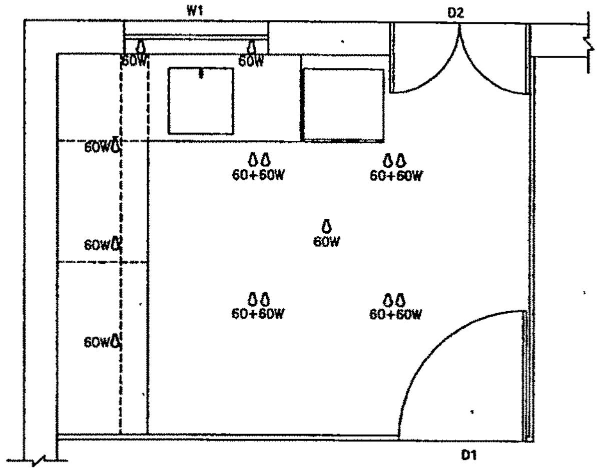


PLATE 10 : LOCATION AND WATTAGE RATING OF LAMPS TO ACHIEVE 500:300 lx FOR FUNCTIONAL AND GENERAL LIGHTING (INCANDESCENT LAMPS)

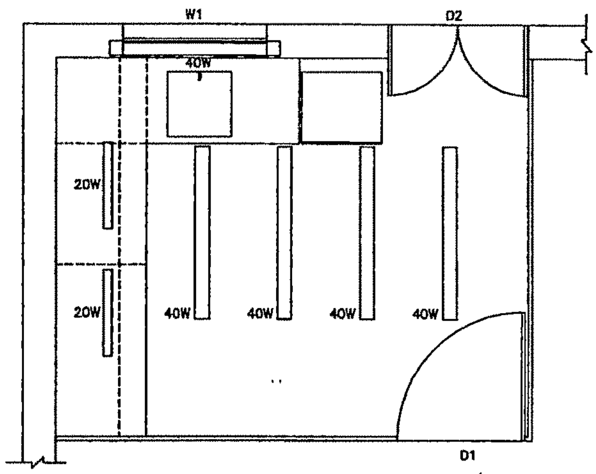


PLATE 11 : LOCATION AND WATTAGE RATING OF LAMPS TO ACHIEVE 500:300 lx FOR FUNCTIONAL AND GENERAL LIGHTING (CONVENTIONAL FLUORESCENT TUBES)

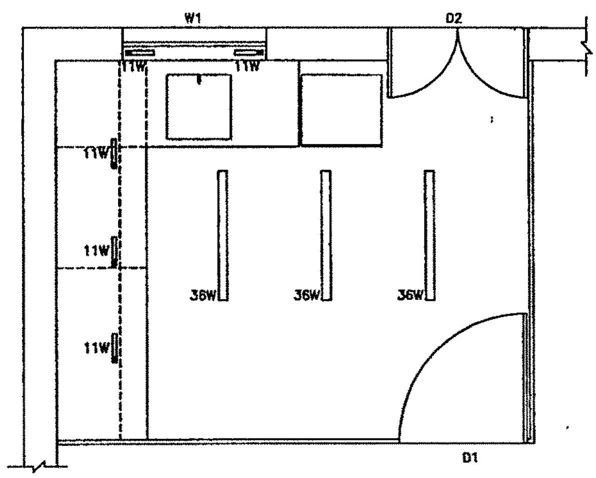


PLATE 12 : LOCATION AND WATTAGE RATING OF LAMPS TO ACHIEVE 500:300 lx FOR FUNCTIONAL AND GENERAL LIGHTING (ENERGY SAVING LAMPS)

SCALE 1:5

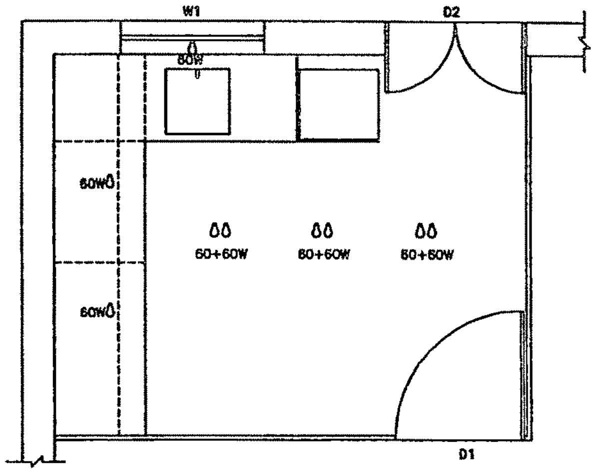


PLATE 13: LOCATION AND WATTAGE RATING OF LAMPS TO ACHIEVE 300:180 lx FOR FUNCTIONAL AND GENERAL LIGHTING (INCANDESCENT LAMPS)

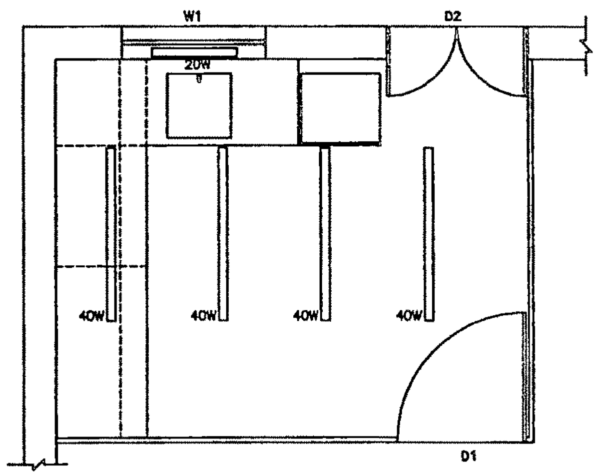


PLATE 14: LOCATION AND WATTAGE RATING OF LAMPS TO ACHIEVE 300:180 lx FOR FUNCTIONAL AND GENERAL LIGHTING (CONVENTIONAL FLUORESCENT TUBES)

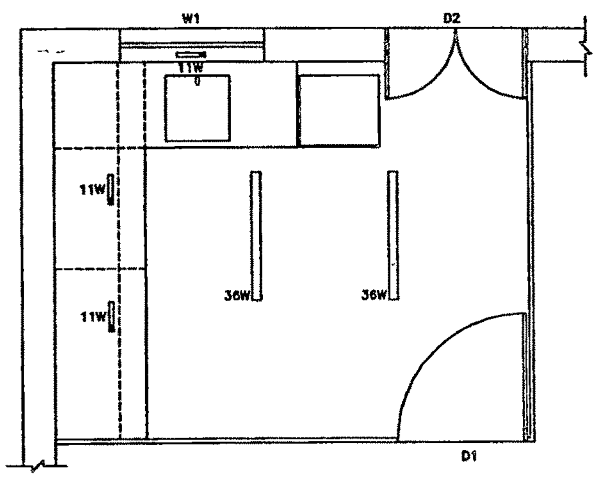


PLATE 15: LOCATION AND WATTAGE RATING OF LAMPS TO ACHIEVE 300:180 lx FOR FUNCTIONAL AND GENERAL LIGHTING (ENERGY SAVING LAMPS)

SCALE 1:5

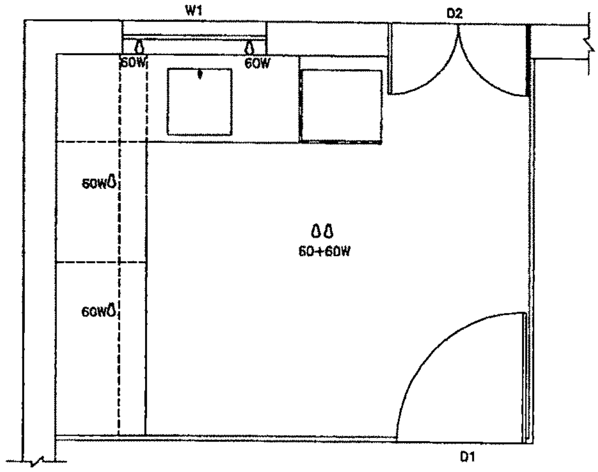


PLATE 16: LOCATION AND WATTAGE RATING OF LAMPS TO ACHIEVE 200:120 lx FOR FUNCTIONAL AND GENERAL LIGHTING (INCANDESCENT LAMPS)

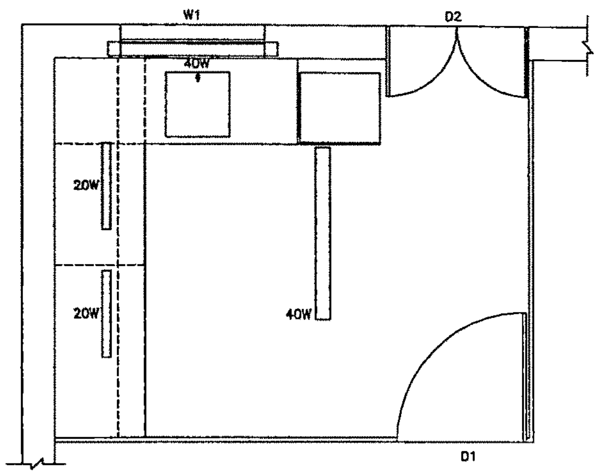


PLATE 17: LOCATION AND WATTAGE RATING OF LAMPS TO ACHIEVE 200:120 lx FOR FUNCTIONAL AND GENERAL LIGHTING (CONVENTIONAL FLUORESCENT TUBES)

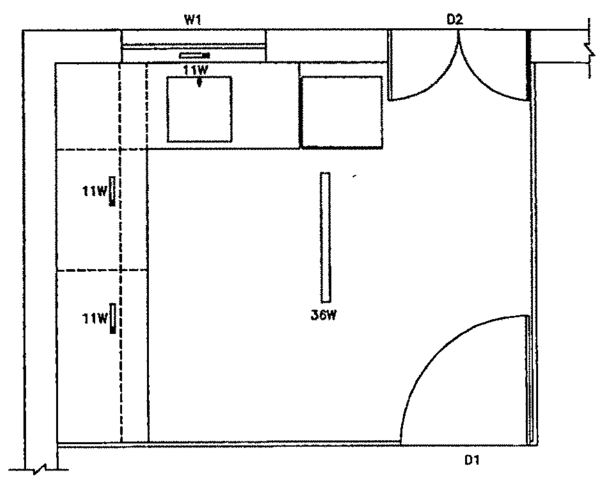


PLATE 18: LOCATION AND WATTAGE RATING OF LAMPS TO ACHIEVE 200:120 lx FOR FUNCTIONAL AND GENERAL LIGHTING (ENERGY SAVING LAMPS)

SCALE 1:5

For general lighting, bright, well-diffused, evenly spaced light sources from the ceiling reflect an appropriate approach to ensure uniformly lighted area that is free of shadows or glare. An efficient way to light up the work counter is having strip lighting, either incandescent, linear fluorescent or compact fluorescent, mounted beneath the wall cabinets. The light source should be installed below the front edge of the cabinets, with an overhang (a narrow pelmet / decorative strip) to conceal the light source and direct the light down.

Bearing in mind the lighting requirements in qualitative and quantitative terms, the position and wattage rating of the lamps are recommended as in plates 11, 12, 14, 15, 17 and 18. The kitchen lighting installations with incandescent lamps as in plate 10, 13 and 16 are provided as a measure of comparison to project the monetary and electric power saving that can be achieved through energy saving modern lamps and conventional fluorescent lamps.

7.0 COMPARATIVE ECONOMICS OF SELECTED LIGHTING INSTALLATIONS AGAINST INCANDESCENT LIGHTING INSTALLATIONS

Economics of selected lighting installations that have capacity to provide good visibility condition and comfortable visual environment in the kitchen are presented in Tables 56 to 61. The findings of the present study indicated that illuminance of 300 and 180 lx for task and general lighting was as good as 500 and 300 lx for task and general lighting respectively. Further the illuminance of 166 and 102 lx for task and general lighting respectively was also found to cater to most of the task performance as evidenced through laboratory experimentation in the simulated kitchen. A higher illuminance of 200 lx which is line with minimum recommended illuminance of Australia for task lighting in the kitchen was considered for Indian kitchen of an average family. Thus three different illuminance conditions for kitchen, namely, 500:300 lx, 300:180 lx and 200:120 lx are recommended with two different types of lighting to choose from. The result of experiments revealed that activities like cutting vegetables, kneading dough or cleaning water glasses, which do not have minute details, could be easily performed under an illuminance of 166 lx. However, when it comes to fine tasks like cleaning 'masalas' like cumin seeds, mustard seeds, sesame and 'ajwain' or cleaning small kitchen tools, where high visual acuity is required, a minimum illuminance of 300 lx is required.

Even though, all these three recommended conditions provide illuminance of desirable quantity and quality in the kitchen, the most economical and the least electric power intensive illuminance is achieved by following the proportion of 200:120 lx for task and general lighting using the energy saving lamps. Notwithstanding this, an illuminance of 300:180 lx is recommended as ideal lighting for kitchen, in view of the fact that this would cater to tasks with minute details as well. On the other hand, an illuminance of 500:300 lx though desirable as per International Standards, does not appear to add to visual acuity in a significant manner (Table 52). Hence provision of such high illuminance apparently does not seem to be an ideal option in the context of prevailing energy crisis and the economic position of average Indian family.

The selected lighting installations include fluorescent lamps of conventional type in both general and task lighting and fluorescent lamps of trulite type for general lighting and compact fluorescent lamps for task lighting. The recommended lighting installations are made primarily for a medium size kitchen (8.82 m^2) with an L-shape layout of platform. However, these can also be applicable to other sizes and layouts of platform with appropriate adjustments. In computing the economics of recommended lighting installations, the relative additional initial costs are calculated which includes the extra capital cost to be incurred in purchase of lamps/luminaires and the interest that it would have fetched as well as the depreciation involved.

The Tables 56 to 61 depict a comparative picture of economics of the selected lamp types, for general lighting and task lighting (with and without diffusers) for each of the three selected illuminance conditions. A comparison amongst the economics of use of incandescent lamps, conventional fluorescent lamps and energy saving lamps revealed that although, a high capital cost is involved in the energy saving system, the choice of the same offers long term financial benefits when compared to incandescent lamps or conventional fluorescent lamps. In a period of about 4 ½ years these benefits would range between Rs. 5000.00 to Rs.15,500.00 when compared to incandescent lamps, and Rs. 550.00 to Rs. 2600.00 when compared to conventional fluorescent lamps ; the lowest value being the saving in fiscal terms for illuminances of 200:120 lx and the highest value being the saving for 500:300 lx with (in between) that of 300:180 lx falling in between these two values for task and general lighting respectively under each of the recommended illuminances.

Comparison between use of energy saving lamps and incandescent lamps revealed that the monetary benefits in the former case is of a higher order for higher illuminance conditions, and in the case of lamps with diffusers for general lighting. When the comparisons were made against conventional fluorescent lamps in a similar manner, the monetary savings appeared to be of a lesser magnitude.

The saving in electric power due to use of energy saving lamps is also substantial, the same being the most in the case of higher illuminance of 500:300 lx as compared to that of 200:120 lx for task and general lighting respectively. However, when relative proportionate saving is estimated, energy saving installations lead to nearly 70 to 75 per cent saving as compared to incandescent lamps at the highest as well as the lowest recommended illuminance as compared to 30 to 35 per cent of conventional fluorescent lamps. If the saving that can be effected in kitchen lighting alone is considered in the case of all family residential units (assuming about 72 million in urban areas), it amounts to as large a saving as 864 megawatt to 5904 megawatt in the case of the lowest to the highest recommended illuminance. There is no doubt that the transition from incandescent or fluorescent to energy saving lamps would lead to a reduction in electric power generation cost per capita. Further, a substantial reduction in CO_2 emissions too would take place and this would lead to reduced global warming as well. Energy efficient and energy saving lighting system, thus would lead to sustainable growth. In other words, a switch over from incandescent and fluorescent lamps to energy saving CFL and fluorescent trulite lamps would pave the way for sustainable lighting installations in residential units.

Table 58 : Economics of different lighting installations for Illuminance of 500 lx and 300 lx for functional and general lighting respectively (with diffusers)

Sr No.				
1	Type of lamp General Lighting Functional Lighting	Incandescent lamp (with tranluscent shades) Incandescent lamp	Fluorescent lamp (Conventional with acrylic diffuser) Fluorescent lamp (Conventional)	Fluorescent lamp (Trulite, with acrylic diffuser) CFL
2	Lamp Wattage General Lighting Functional Lighting Total	9 (60 W) 5 (60 W) 840 W	4 (40 W + 12 W) 1 (40 W + 12 W) + 2 (20 W + 12 W) 324 W	3 (36 W + 12 W) 5 (11 W + 5 W) 224 W
3	Capital Cost General Lighting Functional Lighting Total	Rs. 500 x 5 (twin) + Rs. 10 x 9 Rs. 10 x 4 Rs. 2500 + 975 = 3475.00	Rs. 880 x 4 (Rs. 275 x 1) + (Rs. 260 x 2) Rs.4315.00	Rs. 945 x 3 Rs. 450 x 5 Rs. 5085.00
4	Additional Initial Cost	-----	Rs. 840.00 (Against Incandescent lamp)	Rs. 1610.00 (Against Incandescent lamp) Rs. 770.00 (Against conv. Fluor. Lamp)
5	Interest @ 10%	-----	Rs. 84.00 (Against Incandescent lamp)	Rs. 161.00 (Against Incandescent lamp) Rs. 77.00 (Against conv. Fluor. Lamp)
6	Depreciation @ 15%	-----	Rs. 126.00 (Against Incandescent lamp)	Rs. 241.50 (Against Incandescent lamp) Rs. 115.50 (Against conv. Fluor. Lamp)
7	Total additional initial cost	-----	Rs. 1050.00	Rs. 2012.50 (Against Incandescent lamp) Rs. 962.50 (Against conv. Fluor. Lamp)
8	Units of electric power consumed/month with 4½ hours burning per day	113.4	43.75	30.25
9	Operating cost/month (@ Rs. 3.75 per unit)	Rs. 425.25	Rs. 164.00	Rs. 113.50
10	Saving in operating cost/month	-----	Rs. 261.25 (Against Incandescent lamp)	Rs. 312.00 (Against Incandescent Lamp) Rs. 50.50 (Against conv. fluor. Lamp)
11	Payback period for additional initial cost	-----	Approx. 4 months (Against Incandescent lamp)	Approx. 6 ½ months (Against incand. lamp) Approx. 19 months (Against conv. fluor. lamp)
12	Actual saving over the period of use i.e. 55 months (lamp life 1000 hrs for incand. lamp and 7500 hrs for conv. Fluor. lamp and CFL)	-----	Rs. 13,319.00 (Against Incandescent lamp)	Rs. 15148.00 (Against incandescent lamp) Rs. 1815.00 (Against conv. fluor. lamp)

Table 59 : Economics of different lighting installations for Illuminance of 300 lx and 180 lx for functional and general lighting respectively (with diffusers)

Sr No.				
1	Type of lamp General Lighting Functional Lighting	Incandescent lamp (with tranluscent shades) Incandescent lamp	Fluorescent lamp (Conventional with acrylic diffuser) Fluorescent lamp (Conventional	Fluorescent lamp (Trulite, with acrylic diffuser) CFL
2	Lamp Wattage General Lighting Functional Lighting Total	6 (60 W) 3 (60 W) 540 W	3 (40 W + 12 W) 1 (40 W + 12 W) + 1 (20 W + 12 W) 240 W	2 (36 W + 12 W) 3 (11 W + 5 W) 144 W
3	Capital Cost General Lighting Functional Lighting Total	Rs. 500 x 3 (twin) + Rs. 10 x 6 Rs. 10 x 3 Rs. 1500 + 675 = 2175	Rs. 880 x 3 (Rs. 275 x 1) + (Rs. 260 x 1) Rs. 3175.00	Rs. 945 x 2 Rs. 450 x 3 Rs. 3240.00
4	Additional Initial Cost	-----	Rs. 1000.00 (Against Incandescent lamp)	Rs. 1065.00 (Against Incandescent lamp) Rs. 65.00 (Against conv. fluor. Lamp)
5	Interest @ 10%	-----	Rs. 100.00 (Against Incandescent lamp)	Rs. 106.50 (Against Incandescent lamp) Rs. 6.50 (Against conv. fluor. Lamp)
6	Depreciation @ 15%	-----	Rs. 150.00 (Against Incandescent lamp)	Rs. 159.75 (Against Incandescent lamp) Rs. 9.75 (Against conv. fluor. Lamp)
7	Total additional initial cost	-----	Rs. 1250.00	Rs. 1331.25 (Against Incandescent lamp) Rs. 81.25 (Against conv. fluor. Lamp)
8	Units of electric power consumed/month with 4½ hours burning per day	72.9	32.4	19.44
9	Operating cost/month (@ Rs. 3.75 per unit)	Rs. 273.00	Rs. 121.50	Rs. 73.00
10	Saving in operating cost/month	-----	Rs. 152.50 (Against Incandescent lamp) -----	Rs. 200.00 (Against Incandescent Lamp) Rs. 48.50 (Against conv. fluor. Lamp)
11	Payback period for additional initial cost	-----	Approx. 8 months (Against Incandescent lamp)	Approx. 6 ½ months (Against incand. lamp) Approx. 1 ½ months (Against conv. fluor. lamp)
12	Actual saving over the period of use i.e. 55 months (lamp life 1000 hrs for incand. lamp and 7500 hrs for conv. Fluor. lamp and CFL)	-----	Rs. 7137.50 (Against Incandescent lamp)	Rs. 9669.00 (Against incandescent lamp) Rs. 2586.25 (Against conv. fluor. lamp)

Table 60 : Economics of different lighting installations for Illuminance of 200 lx and 120 lx for functional and general lighting respectively (with diffusers)

Sr No.				
1	Type of lamp General Lighting Functional Lighting	Incandescent lamp (with tranluscent shades) Incandescent lamp	Fluorescent lamp (Conventional with acrylic diffuser) Fluorescent lamp (Conventional	Fluorescent lamp (Trulite, with acrylic diffuser) CFL
2	Lamp Wattage General Lighting Functional Lighting Total	4 (60 W) 2 (60 W) 360 W	2 (40 W + 12 W) 2 (40 W + 12 W) + 1 (20 W + 12 W) 168 W	1 (36 W + 12 W) + 1 (11 W + 5 W) 2 (11 W + 5 W) 96 W
3	Capital Cost General Lighting Functional Lighting Total	Rs. 500 x 2 (twin) + Rs. 10 x 4 Rs. 10 x 2 Rs. 1000 + 60 = 1060 (for 1000 burning hrs) Rs. 1000 + 450 = 1450 (for 7500 burning hrs)	Rs. 880 x 2 Rs. 260 x 2 Rs. 2280.00	(Rs. 945 x 1) + (Rs. 450 x 1) Rs. 450 x 2 Rs. 2295.00
4	Additional Initial Cost	-----	Rs. 830.00 (Against Incandescent lamp)	Rs. 845.00 (Against Incandescent lamp) Rs. 15.00 (Against conv. Fluor. Lamp)
5	Interest @ 10%	-----	Rs .83.00 (Against Incandescent lamp)	Rs. 84.50 (Against Incandescent lamp) Rs. 1.50 (Against conv. Fluor. Lamp)
6	Depreciation @ 15%	-----	Rs. 124.50 (Against Incandescent lamp)	Rs. 126.75 (Against Incandescent lamp) Rs. 2.25 (Against conv. Fluor. Lamp)
7	Total additional initial cost	-----	Rs. 1037.50(Against Incandescent lamp)	Rs. 1056.25 (Against Incandescent lamp) Rs. 18.75 (Against conv. Fluor. Lamp)
8	Units of electric power consumed/month with 4½ hours burning per day	48.60	22.68	12.96
9	Operating cost/month (@ Rs. 3.75 per unit)	Rs. 182.25	Rs. 85.00	Rs. 48.60
10	Saving in operating cost/month	-----	Rs. 97.00 (Against Incandescent lamp) -----	Rs. 134.00 (Against Incandescent Lamp) Rs. 36.50 (Against conv. fluor. Lamp)
11	Payback period for additional initial cost	-----	Approx. 10 ½ months (Against Incandescent lamp)	Approx. 8 months (Against incand. lamp) Approx. 15 days (Against conv. fluor. lamp)
12	Actual saving over the period of use i.e. 55 months (lamp life 1000 hrs for incand. lamp and 7500 hrs for conv. Fluor. lamp and CFL)	-----	Rs. 4298.00 (Against Incandescent lamp)	Rs. 6314.00 (Against incandescent lamp) Rs. 1989.00 (Against conv. fluor. lamp)

Table 61 : Economics of different lighting installations for Illuminance of 500 lx and 300 lx for functional and general lighting respectively (without any diffusers)

Sr No.				
1	Type of lamp General Lighting Functional Lighting	Incandescent lamp Incandescent lamp	Fluorescent lamp (Conventional) Fluorescent lamp (Conventional)	Fluorescent lamp (Trulite) CFL
2	Lamp Wattage General Lighting Functional Lighting Total	7 (60 W) 5 (60 W) 720 W	3 (40 W + 12 W) 1 (40 W + 12 W) + 2 (20 W + 12 W) 272 W	2 (36 W + 12 W) 5 (11 W + 5 W) 176 W
3	Capital Cost General Lighting Functional Lighting Total	Rs. 10 x 7 Rs. 10 x 5 Rs. 120.00 (for 1000 burning hours) Rs. 900.00 (for 7500 burning hours)	Rs. 275 x 3 (Rs. 275 x 1) + (Rs. 260 x 2) Rs. 1620.00	Rs. 340 x 2 Rs. 450 x 5 Rs. 2930
4	Additional Initial Cost	-----	Rs. 720.00(Against Incandescent lamp)	Rs. 2030.00 (Against Incandescent Lamp) Rs. 1310.00 (Against Fluorescent Lamp)
5	Interest @ 10%	-----	Rs. 72.00 (Against Incandescent lamp)	Rs. 203.00 (Against Incandescent Lamp) Rs. 131.00 (Against Fluorescent Lamp)
6	Depreciation @ 15%	-----	Rs. 108.00 (Against Incandescent lamp)	Rs. 304.50 (Against Incandescent Lamp) Rs. 196.50 (Against Fluorescent Lamp)
7	Total additional initial cost	-----	Rs. 900.00 (Against Incandescent lamp)	Rs. 2537.50 (Against Incandescent Lamp) Rs. 1637.50 (Against Fluorescent Lamp)
8	Units of electric power consumed/month with 4½ hours burning per day	97.2	36.72	23.76
9	Operating cost/month (@ Rs. 3.75 per unit)	Rs. 364.50	Rs. 137.70	Rs. 89.00
10	Saving in operating cost/month	-----	Rs. 226.80 (Against Incandescent lamp) -----	Rs. 275.50 (Against Incandescent Lamp) Rs. 48.70 (Against Fluorescent Lamp)
11	Payback period for additional initial cost	-----	Approx. 4 months (Against Incandescent lamp)	Approx. 9 ½ months (against incand. lamp) Approx. 33 ½ months (against conv. fluor. lamp)
12	Actual saving over the period of use i.e. 55 months (lamp life 1000 hrs for incand. lamp and 7500 hrs for conv. Fluor. lamp and CFL)	-----	Rs. 11574.00 (Against Incandescent lamp)	Rs. 12,615.00 (against incandescent lamp) Rs. 1,041.00 (against conv. fluor. lamp)

Table 62 : Economics of different lighting installations for Illuminance of 300 lx and 180 lx for functional and general lighting respectively (without any diffusers)

Sr No.				
1	Type of lamp General Lighting Functional Lighting	Incandescent lamp Incandescent lamp	Fluorescent lamp (Conventional) Fluorescent lamp (Conventional	Fluorescent lamp (Trulite) CFL
2	Lamp Wattage General Lighting Functional Lighting Total	4 (60 W) 3 (60 W) 420 W	2 (40 W + 12 W) 1 (40 W + 12 W) + 1 (20 W + 12 W) 188 W	1 (36 W + 12 W) + 1 (18 W + 12 W) 3 (11 W + 5 W) 126 W
3	Capital Cost General Lighting Functional Lighting Total	Rs. 10 x 4 Rs. 10 x 3 Rs. 70.00 (for 1000 burning hours) Rs. 525.00 (for 7500 burning hours)	Rs. 275 x 2 (Rs. 275 x 1) + (Rs. 260 x 1) Rs. 1085.00	Rs. 340 x 1 + Rs. 311 x 1 Rs. 450 x 3 Rs. 2001.00
4	Additional Initial Cost	-----	Rs. 560.00 (Against Incandescent lamp)	Rs. 1476.00 (Against Incandescent Lamp) Rs. 916.00 (Against Fluorescent Lamp)
5	Interest @ 10%	-----	Rs. 56.00 (Against Incandescent lamp)	Rs. 147.60 (Against Incandescent Lamp) Rs. 91.60 (Against Fluorescent Lamp)
6	Depreciation @ 15%	-----	Rs. 84.00 (Against Incandescent lamp)	Rs. 221.40 (Against Incandescent Lamp) Rs. 137.40 (Against Fluorescent Lamp)
7	Total additional initial cost	-----	Rs. 700.00 (Against Incandescent lamp)	Rs. 1845.00 (Against Incandescent Lamp) Rs. 1145.00 (Against Fluorescent Lamp)
8	Units of electric power consumed/month with 4½ hours burning per day	56.7	25.38	17.01
9	Operating cost/month (@ Rs. 3.75 per unit)	Rs. 213.00	Rs. 95.00	Rs. 64.00
10	Saving in operating cost/month	-----	Rs. 118.00 (Against Incandescent lamp) -----	Rs. 149.00 (Against Incandescent Lamp) Rs. 31.00 (Against Fluorescent Lamp)
11	Payback period for additional initial cost	-----	Approx. 6 months (Against Incandescent lamp)	Approx. 12 ½ months (against incand. lamp) Approx. 37 months (against conv. fluor. lamp)
12	Actual saving over the period of use i.e. 55 months (lamp life 1000 hrs for incand. lamp and 7500 hrs for conv. Fluor. lamp and CFL)	-----	Rs. 5790.00 (Against Incandescent lamp)	Rs. 6350.00 (against incandescent lamp) Rs. 560.00 (against conv. fluor. lamp)

Table 63 : Economics of different lighting installations for Illuminance of 200 lx and 120 lx for functional and general lighting respectively (without any diffusers)

Sr No.				
1	Type of lamp General Lighting Functional Lighting	 Incandescent lamp Incandescent lamp	 Fluorescent lamp (Conventional) Fluorescent lamp (Conventional	 Fluorescent lamp (Trulite) CFL
2	Lamp Wattage General Lighting Functional Lighting Total	 3 (60 W) 2 (60 W) 300 W	 1 (40 W + 12 W) + 1 (20 W + 12 W) 2 (20 W + 12 W) 148 W	 1 (36 W + 12 W) 2 (11 W + 5 W) 80 W
3	Capital Cost General Lighting Functional Lighting Total	 Rs. 10 x 3 Rs. 10 x 2 Rs. 50.00 (for 1000 burning hours) Rs. 375.00 (for 7500 burning hours)	 Rs. 275 x 1 + Rs. 260 x 1 Rs. 260 x 2 Rs. 1055.00	 Rs. 340 x 1 Rs. 450 x 2 Rs. 1240.00
4	Additional Initial Cost	-----	Rs. 680.00(Against Incandescent lamp)	Rs. 865.00 (Against Incandescent Lamp) Rs. 185.00 (Against Fluorescent Lamp)
5	Interest @ 10%	-----	Rs. 68.00 (Against Incandescent lamp)	Rs. 86.50 (Against Incandescent Lamp) Rs. 18.50 (Against Fluorescent Lamp)
6	Depreciation @ 15%	-----	Rs. 102.00 (Against Incandescent lamp)	Rs. 129.75 (Against Incandescent Lamp) Rs. 27.75 (Against Fluorescent Lamp)
7	Total additional initial cost	-----	Rs. 850.00 (Against Incandescent lamp)	Rs. 1081.50 (Against Incandescent Lamp) Rs. 231.25 (Against Fluorescent Lamp)
8	Units of electric power consumed/month with 4½ hours burning per day	40.5	19.98	10.8
9	Operating cost/month (@ Rs. 3.75 per unit)	Rs. 152.00	Rs. 75.00	Rs. 40.50
10	Saving in operating cost/month	-----	Rs. 77.00 (Against Incandescent lamp) -----	Rs. 112.00 (Against Incandescent Lamp) Rs. 34.50 (Against Fluorescent Lamp)
11	Payback period for additional initial cost	-----	Approx. 11 months (Against Incandescent lamp)	Approx. 9 ½ months (against incand. lamp) Approx. 7 months (against conv. fluor. lamp)
12	Actual saving over the period of use i.e. 55 months (lamp life 1000 hrs for incand. lamp and 7500 hrs for conv. Fluor. lamp and CFL)	-----	Rs. 3385.00 (Against Incandescent lamp)	Rs. 5079.00 (against incandescent lamp) Rs. 1666.25 (against conv. fluor. lamp)