APPENDIX "B"

RANGE OF OBJECTIONABLE VOLTAGE FLICKER

Certain types of utilization equipment such as motors have a high initial inrush current when turned on and impose a heavy load at a low power factor for a very short time. This sudden increase in the current flowing to the load causes a momentary increase in the current flowing to the load causes a momentary increase in the voltage drop along the distribution system, and a corresponding reduction in the voltage at the utilization equipment. A voltage dip of 1/4-1/2% will cause a noticeable reduction in the light output of an incandescent lamp and a less noticeable reduction in the light output of gaseous discharge lighting equipment.

In general, the starting current of a standard motor averages about 5 times the full-load running current. The approximate values for all ac motors over 1/2 hp are indicated by a code letter on the nameplate of the motor. The values indicated by these code letters are given in ANSI/NEMA MGO-1978[8] and also in Article 430 of the NEC [9].

A motor requires about 1 kVA for each motor horsepower in normal operation, so the starting current of the average motor will be about 5 kVA for each motor horsepower. When the motor rating in horsepower approaches 5% of the secondary unit substation transformer capacity in kilovolt-amperes, the motor starting apparent power approaches 25% of the transformer capacity which, with a transformer impedance voltage of 6-7%, will result in a noticeable voltage dip on the order of 1%.

In addition, a similar voltage dip will occur in the wiring between the secondary unit substation and the motor when starting a motor with a full-load voltage drop on the order of 4 or 5%. However, the voltage drop is distributed along the circuit so that maximum dip occurs only when the motor is moved from the far end to the beginning of the circuit, the voltage drop in the circuit approaches zero. As the affected equipment is moved from the far end to the beginning of the circuit, the voltage dip remains constant up to the point of connection of the motor and then decreases to zero as the equipment connection approaches the beginning of the circuit.

The total voltage dip is the sum of the dip in the secondary unit substation transformer and the secondary circuit. In the case of very large motors of several hundred to a few thousand horsepower, the impedance of the supply system should be considered.

Where loads are turned on and off rapidly as in the case of resistance welders, or fluctuate rapidly as in the case of arc furnaces, the rapid fluctuations in the light output of incandescent lamps, and to a lesser extent, gaseous discharge lamps, is called flicker. When flicker continues over an appreciable period, voltage variations as low as 1/2% may be objectionable. If utilization equipment involving rapidly fluctuating loads is on the order of 10% of the capacity of the secondary unit substation transformer and the secondary circuit, accurate calculations should be made using the actual load currents and system impedance to determine the effect on lighting equipment.

Figure B1 may be used to determine whether voltage fluctuations will cause objectionable fluctuations in the light output of incandescent lamps. The borderline of irritation curve starts with a voltage change of 1% at a frequency of 7 fluctuations per second and increases to about 6% at 1 fluctuation per minute. The range between permissible flicker and objectionable flicker is due to the

fact that some people are bothered more than others. Also, the effect of flicker depends upon lighting intensity and working conditions. Tests have indicated that flicker that is irritable to some people is hardly noticed by other people. Flicker is more of a problem with incandescent lighting than with fluorescent and high-intensity discharge types.

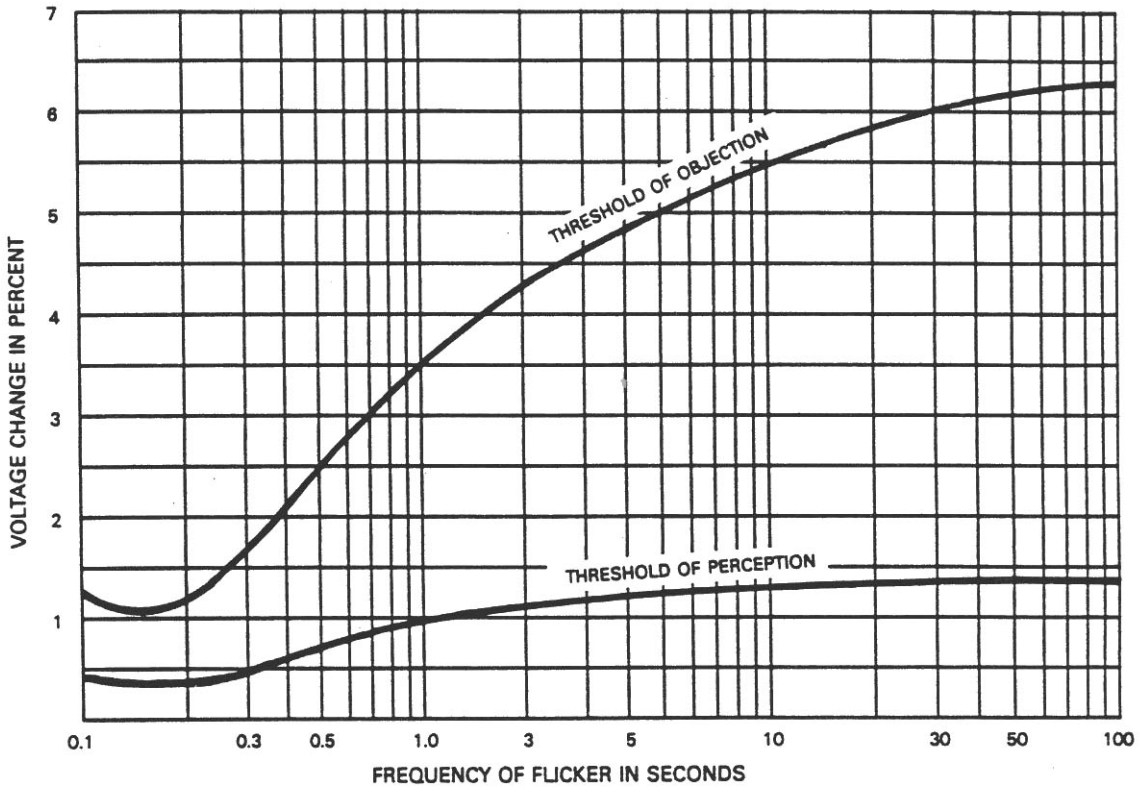

Fig B1
Range of Observable and Objectionable Voltage Flicker Versus Time

In using this curve, the purpose for which the lighting is provided needs to be considered. For example, lighting used for close work such as drafting requires flicker limits approaching the borderline of visibility curve. For general area lighting such as storage areas, the flicker limits may approach the borderline of the irritation curve. Note that the effect of voltage dips depends on the frequency of occurrence. An occasional dip, even though quite large, is rarely objectionable.

When objectionable flicker occurs, either the load causing the flicker should be reduced or eliminated, or the capacity of the supply system increased to reduce the voltage drop caused by the fluctuating load. In large plants, flicker-producing equipment should be segregated on separate transformers and feeders so as not to disturb flicker-sensitive equipment.

Special consideration should always be given when starting larger motors to minimize the voltage dip so as not to affect the operation of other utilization equipment on the system supplying the motor. Large motors (see Table 1) may be supplied at medium voltage such as 2,400, 4,160 or 12,470 V from a separate transformer to eliminate the voltage dip on the low-voltage system. However, consideration should be given to the fact that the maintenance electricians may not be qualified to maintain medium-voltage equipment. A contract with a qualified electrical firm may

be required for maintenance. Standard voltages and preferred horsepower limits for polyphase induction motors are shown in Table 12.

Table 1
Standard Voltages and Preferred Horsepower Limits
for Polyphase Induction Motors

Motor Nameplate Voltage	**Preferred Horsepower Limits**
Low Voltage Motors:	
115	No Minimum – 15 hp Maximum
230	No Minimum – 200 hp Maximum
460 and 575	1 hp Minimum – 1,000 hp Maximum
Medium Voltage Motors:	
2,300	50 hp Minimum – 6,000 hp Maximum
4,000	100 hp Minimum – 7,500 hp Maximum
4,500	250 hp Minimum – No Maximum
6,000	400 hp Minimum – No Maximum
13,200	1,500 hp Minimum – No Maximum

Objectionable dips in the supply voltage from the utility should be reported to the utility for correction.