ILUMINACION EFICIENTE Y SU CONTROL EN EDIFICIOS NO RESIDENCIALES

DEL 24 DE ABRIL AL 9 DE MAYO

DIA		HORA	TEMA	EXPOSITOR
ABRIL				
LUNES	24	17:00 a 18:00	OBJETIVO DEL CURSO	ING CARLOS GARCIA R
		18:00 a 19:00	TARIFAS ELECTRICAS	ING ALEX RAMIREZ
		19:00 a 21:00	TERMINOLOGIA	ING ALEX RAMIREZ
MARTES	25	17:00 a 21:00	LAMPARAS	ING ALFREDO BADILLO
MIERCOLES	26	17:00 a 21:00	BALASTROS	ING ERNESTO MENDOZA
JUEVES	27	17:00 a 19:00	FOTOMETRIA	ING JOSE LUIS BONILLA
		19:00 a 21:00	LUMINARIOS	ING JOSE LUIS BONILLA
VIERNES	28	17:00 a 21:00	CONTROLES	ING CARLOS MENDOZA
MAYO				
MARTES	2	17:00 a 19:00	RECOMENDACIONES Y NORMATIVIDAD	ING CARLOS GARCIA
		19:00 a 21:00	PROCEDIMIENTO DE CALCULO ZONAL	ING CARLOS GARCIA R
MIERCOLES	3	17:00 a 19:00	ILUMINACION DE ESTACIONAMIENTOS	ING CARLOS GARCIA R
		19:00 a 21:00	EJERCICIO DE CALCULO	ING CARLOS GARCIA R
JUEVES	4	17:00 a 21:00	DESARROLLO DE UN PROYECTO	ING CARLOS GARCIA R
LUNES	8	17:00 a 21:00	DESARROLLO DE UN PROYECTO	ING CARLOS GARCIA R
MARTES	9	17:00 a 19:00	DESARROLLO DE UN PROYECTO	ARQ ENRIQUE QUINTERO I
		19:00 a 20:00	MESA REDONDA	ING CARLOS GARCIA R
		20:00 a 21:00	CLAUSURA	ING CARLOS GARCIA R

FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

T E M A 1

TARIFAS ELECTRICAS.

ING. ALEX RAMIREZ RIVERO.

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TEMA 1
TARIFAS ELECTRICAS

INTRODUCCION

Haciendo caso omiso de los muchos tipos de tarifas y de los ....entes procedimientos de cálculo de cualquier compañía de generación de energía eléctrica del mundo, todas las facturas extendidas sobre el consumo de fuerza obedecen al mismo patrón.

Por lo común hay tres conceptos de cargo para formular estas facturas: demanda máxima, energía consumida y factor de potencia.

Los cargos por concepto de la demanda se basan en los costos de generación de energía eléctrica, de la transmisión y distribución de la misma, de acuerdo con los medios disponibles para efectuarlas.

En este renglón se incluyen los cargos redituables de la inversión, agregando intereses, impuestos, amortización, etc. Los cargos por concepto de energía comprenden los costos del combustible, mantenimiento y otros gastos relacionados con la operación.

II.1.- CARGOS POR DEMANDA MAXIMA

La demanda máxima puede explicarse de la manera siguiente: Supongamos que una planta va a fabricar botes de hojalata y que el rendimiento de cada máquina es de 10, 000 botes diarios, una orden de 300, 000 botes requiera 30 máquinas para fabricar este volumen en un día, pero si esta orden se reparte entre 10 días, la planta podrá trabajar con sólo tres máquinas.

El valor de la inversión representado por las máquinas tiene que incluirse en el costo de la producción de los botes. Si se puede convencer al comprador para que espere más tiempo para recibir sus botes, se le podrá dar un precio más reducido. Sise reducen los gastos generales, se podrá obtener un precio más bajo por unidad.

Lo mismo sucede con el caso de la Energía Eléctrica, sólo que en este renglón no le queda a la Central de Generación Eléctrica ninguna alternativa. Al hacer funcionar el

Para poder reducir y controlar su demanda, los usuarios deben reorganizar sus operaciones según el proceso se los permita para distribuir su demanda fuera de las horas pico; o bien limitar en forma automática la demanda mediante algún sistema controlador. En ambos casos el primer paso consiste en hacer un análisis que permita conocer las características de la demanda durante un período dado. En este análisis se deben considerar los siguientes factores:

1. Factor de carga
2. Valor y duración de los picos de demanda
3. Valor y duración de los valles
4. Horario de los picos de demanda
5. Causas de los picos de demanda

II.4.- CARGOS POR ENERGIA CONSUMIDA

Los costos de operación de la porción de la factura de consumo de energía eléctrica, se basan en el número de kilowatts-hora registrados en el término de cierto período, normalmente por un mes. Para establecer comparaciones, tómese en consideración este período de facturación. El número de días de trabajo y el número de días cubiertos tendrán diferencias.

Existen cuatro situaciones en las que se deben considerar las pérdidas en el transformador:

1. Si el usuario tiene su contratación en baja tensión, las pérdidas en los transformadores las absorbe la compañía que suministra el servicio.

2. Si el usuario tiene su contratación en media y alta tensión, y su medidor de consumo se encuentra en el secundario del transformador, la compañía que suministra el servicio efectúa un cargo del 2% por concepto de las pérdidas en el transformador.

3. Si el usuario tiene su contratación en media y alta tensión, y su medidor de

consumo se encuentra en el primario del transformador, no se realiza cargo ya que las pérdidas del transformador quedan incluidas en el medidor.

4. Si el suministrador del servicio tiene disponible solo baja tensión y el usuario requiere aumentar su voltaje a media o alta tensión mediante la instalación de un transformador, el suministrador del servicio bonifica el 2% al usuario o se recurre a otro convenio para hacerse cargo de las pérdidas del transformador.

II.5.- CARGOS POR BAJO FACTOR DE POTENCIA

El término factor de potencia puede elevar el monto de la factura de consumo y sus efectos se hacen sentir en otros aspectos en el sistema de distribución de energía eléctrica en toda planta. El factor de potencia es un número que expresa una relación y puede explicarse de la siguiente manera:

La potencia es el producto de la corriente que fluye por el circuito y del voltaje sostenido en el mismo; es decir, es el resultado de multiplicar los amperios por los volts. Sin embargo, en los circuitos de corriente alterna, el amperaje requerido por los motores de inducción, transformadores, alumbrado fluorescente, hornos de inducción, soldadoras por resistencia, etc. está formado por dos clases de corriente: la corriente magnetizante y la corriente que desarrolla el trabajo.

La corriente efectiva es la que se convierte en trabajo útil por la acción del equipo como. por ejemplo, la rotación de un motor, la ejecución de un cordón de soldadura o el bombeo de agua. Esta corriente da como resultado la potencia activa, medida en KW.

La corriente magnetizante (conocida también como corriente reactiva) es aquella que se requiere para producir el flujo magnético necesario para la operación de aparatos de inducción como los anteriormente mencionados. Sin la corriente de magnetización no habrá flujo de energía a través del núcleo de un transformador, ni a través del entrehierro de un motor de inducción. Este tipo de corriente produce la potencia reactiva que se expresa en KVAR. La relación entre el factor de potencia se expresa como la relación entre la corriente productora de potencia y la corriente del circuito.

$$\text{Factor de potencia} = \frac{KW}{KVA}; \quad \text{ó} \quad KW = Kva \times fp.$$

Las facturas de consumo de energía se basan en las mediciones de la demanda y en los Kilowatts-hora de energía.

De la fórmula anterior se desprende que para evitar cierta cantidad de potencia a un consumidor, la Central tendrá que transmitir una corriente mayor hacia un sistema que tenga un factor de potencia bajo, que hacia otro cuyo factor de potencia sea más alto. El valor de la corriente adicional no es registrado por el watthorímetro del consumidor y por lo tanto representa una pérdida para la compañía suministradora. Esta condición exige también la instalación de cables más gruesos y los transformadores, generadores y otros equipos, cuyas características se basan en su capacidad para conducir corriente, tendrán que ser de mayor tamaño.

En atención a la necesidad de compensar el monto de la mayor inversión que se necesita para atender la demanda de cargas de factor de potencia bajo, las compañías de energía eléctrica han introducido la cláusula de factor de potencia para las facturas de consumo de energía. En esta cláusula se ofrece una reducción en las cuotas de consumo para cargas con factor de potencia alto o también imponen cuotas a manera de multa si el factor de potencia está es bajo. Pero el resultado real es que se aplican cargos extra cuando el factor de potencia está por abajo del 90 % en la mayoría de los casos.

II.6.- ESTRUCTURA DE LAS TARIFAS

La estructura actual de las tarifas de energía eléctrica se basa en los costos de suministro a los usuarios, por lo cual se han tomado en cuenta las diferencias regionales, estaciones del año, horarios de consumo, nivel de la tensión de suministro y demanda.

II.6.a.- Regionalización tarifaria

Por lo anterior CFE ha dividido el territorio nacional por regiones, principalmente para diferenciar el uso de la energía eléctrica en media y alta tensión. A continuación se muestra un mapa con las regiones. Los números se refieren a porcentajes de cuotas, con respecto a las cuotas base, al 100 %, que se listan en la sección "cuotas y condiciones".

A continuación se detallan los municipios y estados de la república mexicana que corresponden a cada zona.

1) **REGION BAJA CALIFORNIA**. Todos los municipios del estado de Baja California. Municipios del estado de Sonora: San Luis Río Colorado.

2) **REGION BAJA CALIFORNIA SUR**. Todos los municipios del estado de Baja

California Sur.

3) REGION NOROESTE. Todos los municipios del estado de SONORA, excepto San Luis Río Colorado. Todos los municipios del estado de SINALOA.

4) REGION NORTE. Todos los municipios de los estados de CHIHUAHUA Y DURANGO.

Municipios del estado de ZACATECAS: Chalchihuites, Jimenéz del Téul, Sombreretes, Saín Alto, Jerez, Juan Aldama, Río Grande, General Francisco Murguía, Mazapil, Melchor Ocampo.

Municipios del estado de COAHUILA: San Pedro de las Colonias, Matamoros, Viesca, Parras de la Fuente y Francisco I. Madero.

5) REGION NORESTE. Todos los municipios de los estados de NUEVO LEON Y TAMAULIPAS.

Todos los municipios del estado de COAHUILA excepto los comprendidos en la REGION NORTE.

Municipios del estado de ZACATECAS: Concepción del Oro y El Salvador.

Municipios del estado de SAN LUIS POTOSI: Venegas, Cedral, Cerritos, Guadalcázar, Ciudad Fernández, Río Verde, San Ciro de Acosta, Lagunillas, Santa Catarina, Rayón Cardenas, Alquines, Ciudad del Maíz, Ciudad Valles, Tamazopo, Aquismon, Axtla de Terrazas, Tamazunchale, Huehuetlán, Tamuín, Tancahuitz, Tanlajas, San Antonio Coscatlán, Tampamolón, San Vicente Tancuayalab, Ebano, Xilitla, Tampacan.

Municipios del estado de VERACRUZ: Pánuco, temporal, Pueblo Viejo, Tampico Alto, Ozuluama de Mazcareñas, El Higo, Huayacocotla.

6) REGION CENTRAL. Todas las delegaciones del DISTRITO FEDERAL. Municipios del estado de MEXICO: Tultepec, Tultitlán, Ixtapaluca, Chalco de Días Covarrubias, Huixquilucan de Degollado, San Mateo Atenco, Toluca, Santa Cruz Atizapán, Cuatitlán, Coacalco, Cuatitlán Izcalli, Atizapán de Zaragoza, Tlalnepantla, Naucalpan de Juárez, Ecatepec, Chimalhuacán, Chiciloapan, Texcoco, Ciudad Netzahualcóyotl, Los Reyes La paz. Municipios del estado de MORELOS: Cuernavaca.

7) REGION SUR. Todos los municipios de los estados de: NAYARIT, JALISCO, COLIMA, MICHOACAN, AGUASCALIENTES, GUANAJUATO, QUERETARO, HIDALGO, GUERRERO, TLAXCALA, PUEBLA, OAXACA, CHIAPAS, TABASCO.

Todos los municipios de los estados de ZACATECAS, SAN LUIS POTOSI Y VERACRUZ no comprendidos en la REGION NORTE o en la REGION NORESTE.

Todos los municipios de los estados de MEXICO Y MORELOS no comprendidos en la REGION CENTRAL.

8) REGION PENINSULAR. Todos los municipios de los estados de YUCATAN, CAMPECHE Y QUINTANA ROO.

II.6.b.- Clasificación y descripción

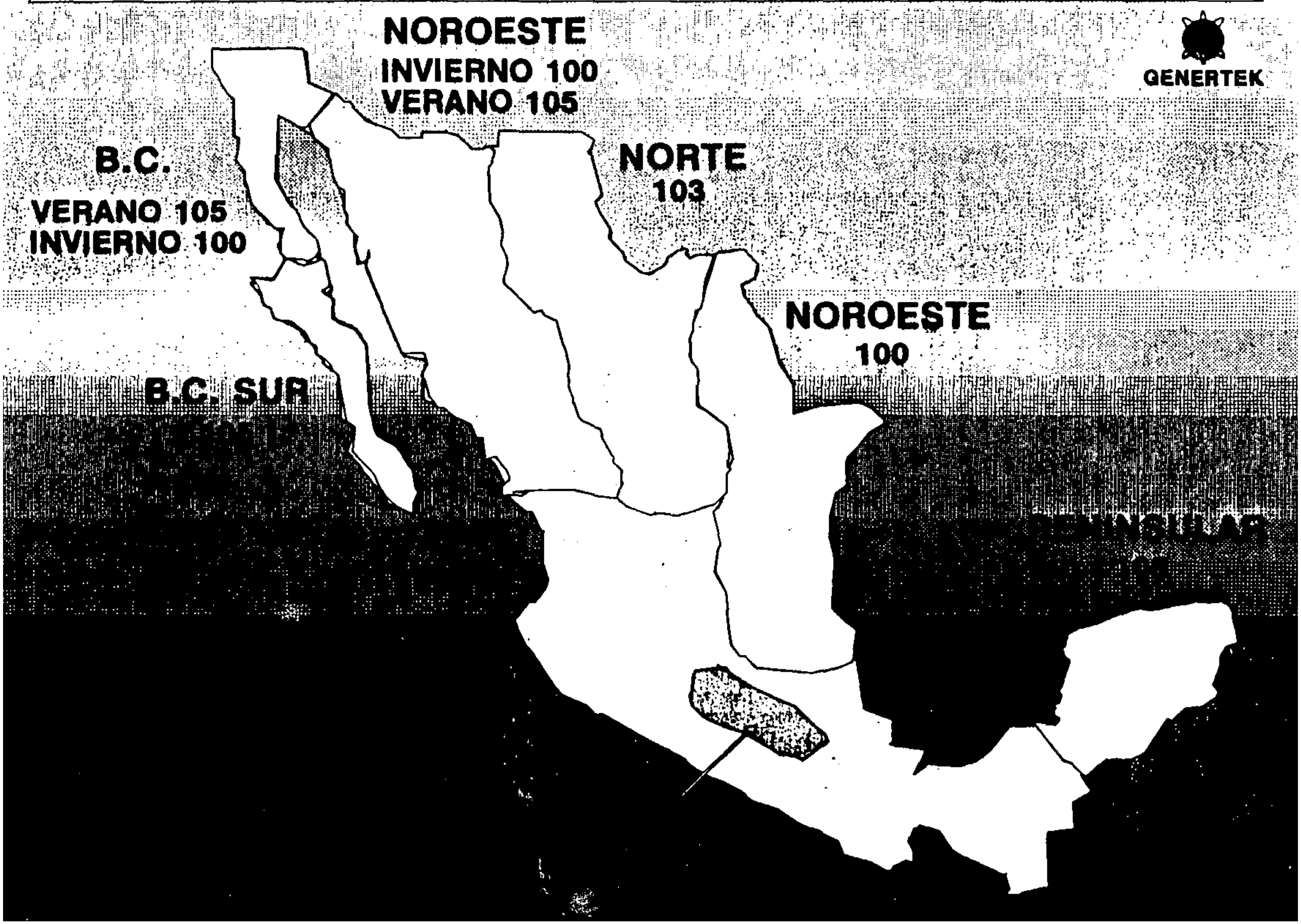
Para la aplicación e interpretación de las tarifas se considera que:

a) Baja tensión es el servicio que se suministra en niveles de tensión menores o iguales a 1.0 KV.
b) Media tensión es el servicio que se suministra en niveles de tensión mayores a 1.0 kV, pero menores o iguales a 35 KV.
c) Alta tensión a nivel subtransmisóm es el servicio que se suministra a niveles de tensión mayores a 35 KV, pero menores a 220 KV.
d) Alta tensión a nivel transmisión es el servicio que se suministra a niveles de tensión iguales o mayores a 220 KV.

TABLA 1
Clasificación y descripción

Tarifa	Denominación	Condiciones de suministro
1	Residencial	Baja tensión sin límite de carga
2	Servicios Generales	Baja tensión y hasta 25 KW
3	Servicios Generales	Baja tensión y cargas mayores de 25 KW
5 y 5A	Alumbrado Público	Alta o Baja tensión sin límite de carga
6	Bombeo aguas	Media o Baja tensión sin límite de carga
7	Servicio temporal	Baja tensión sin límite de carga
9	Bombeo agua riego	Media o Baja tensión sin límite agrícola de carga
OM	Ordinaria media	Media tensión y cargas mayores, tensión a 20 KW y menores de 1000 KW
HM	Horaria media tensión	Media tensión y cargas igual o mayor a 1000 KW
HS	Horaria alta tensión	Alta tensión nivel S de 35 a 220 KV

FACTORES DE REGIONALIZACION TARIFARIA



HT	Horaria alta tensión	Alta tensión nivel T 220 KV ó más
H-SL	Horaria alta tensión	Alta tensión nivel S de 35 a larga utilización y 220 KV
H-TL	Horaria alta tensión	Alta tensión nivel T 220 KV ó más larga utilización
I-30	Servicio Interrumpible	Alta tensión niveles S y T cargas mayores a 20000 KW

II.7.- CONCEPTOS SOBRE LAS CUOTAS

Todas las cuotas que se presentan a continuación, están en N$ (nuevos pesos) y corresponden al mes de enero de 1993. Para calcular las cuotas de las tarifas 1, 2 ,3 7 y 9 de cualquier mes después de enero de 1993, ver el inciso 'cargo por mantenimiento'. Las cuotas que se presentan para las tarifas de la O-M a la I-30 corresponden la región sur. Para calcular otras regiones deben multiplicarse por el factor de regionalización que se muestra en el mapa de la sección 'regionalización tarifaria'.

APLICACION DE LAS TARIFAS 1 A 9

TARIFA 1
RESIDENCIAL

Esta tarifa se aplicará a todos los servicios que destinen la energía para usos exclusivamente domésticos, cualquiera que sea la carga conectada individualmente a cada residencia, apartamento, apartamento en condominio o vivienda. Estos servicios sólo se suministran en baja tensión y no debe aplicárseles ninguna otra tarifa.

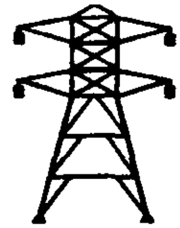
CUOTAS APLICABLES: cargos por energía consumida.

TARIFA 1A, 1B, 1C, 1D

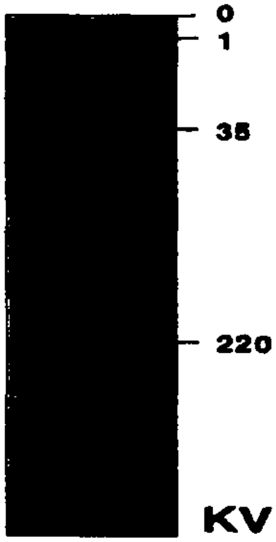
Esta tarifa se aplica a todos los servicios que destinen la energía para uso exclusivamente doméstico, cualquiera que sea la carga conectada individualmente a cada residencia, apartamento, apartamento en condominio o vivienda, en localidades con clima muy cálido. Estos servicios sólo se suministran en baja tensión y no debe aplicárseles ninguna otra tarifa.

LUGARES DONDE REGIRA LA TARIFA. Esta tarifa rige en aquellas localidades con clima muy cálido, considerándose como tales aquellas cuya temperatura media mensual durante 2 meses consecutivos o más, sea de 25 C o mayor, de acuerdo con las observaciones termométricas registradas por la SARH. A continuación se muestra la temperatura que

NIVELES DE TENSION



Para la aplicación e interpretación de las tarifas se considera que:



a) Baja tensión es el servicio que se suministra a niveles de tensión menores ó iguales a 1 KV.

b) Media tensión es el servicio a tensiones mayores a 1 KV pero menores o iguales a 35 KV.

c) Alta tensión a nivel subtransmisión es el servicio a tensiones mayores a 35 KV pero menores a 220 KV.

d) Alta tensión a nivel transmisión es el servicio a tensiones iguales ó mayores a 220 KV.

AGRR/ABR-93

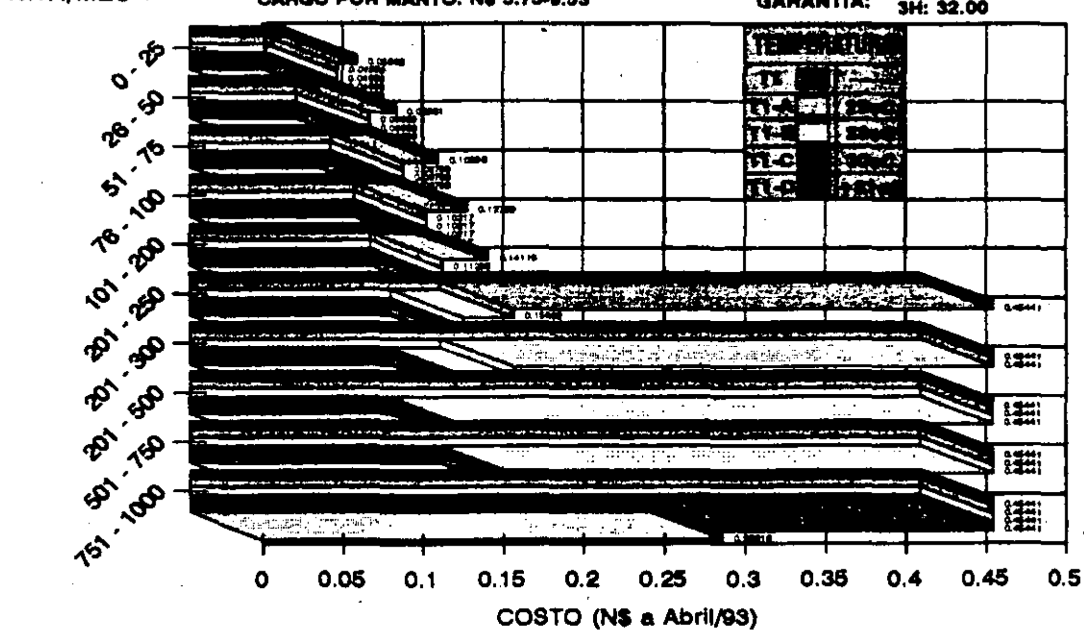
APLICACION DE LA TARIFA 1

USO EXCLUSIVAMENTE DOMESTICO EN BAJA TENSION

CUOTAS APLICABLES : CARGOS POR ENERGIA Y MANTENIMIENTO

MINIMO MENSUAL: N$ 0.453
CARGO POR MANTO: N$ 3.75-9.53

DEPOSITOS EN GARANTIA: 1H: 6.00 2H: 26.00 3H: 32.00



AGRR/ABR-93

corresponde a cada tarifa.

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T - 1A ----------> 25 C
T - 1B ----------> 28 C
T - 1C ----------> 30 C
T - 1D ----------> 31 C ó más
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TABLA 2

TARIFA 2
SERVICIOS GENERALES (hasta 25 KW)

Esta tarifa se aplica a todos los servicios que destinen la energía en baja tensión a cualquier uso, con demanda hasta de 25 kW, excepto a los servicios para los cuales se fija específicamente su tarifa.

CUOTAS APLICABLES. Cargo fijo y cargo por energía consumida.

Cargo Fijo	0-50 KW-h	51-100 KW-h	KW-h adicionales
N$ 4.02504	N$ 0.30331	N$ 0.37933	N$ 0.42406

DEMANDA POR CONTRATAR. La fija inicialmente el usuario de acuerdo con sus necesidades de potencia y no puede ser superior a 25 kW. La tarifa obliga al usuario a solicitar el cambio a la tarifa 3 si la demanda máxima medida excede de 25 kw, y faculta al suministrador a realizar esta reclasificación automáticamente al realizarse la tercera demanda consecutiva o superior, dando aviso al usuario. Para poder realizar, la demanda máxima debe medirse y es obvio que no resulta práctico medir la demanda a todos los usuarios de tarifa 2, por lo que se deben observar las siguientes recomendaciones generales:

Servicios con carga conectada hasta 36 kW
- No medir demanda
- Facturación bimestral

Servicios con carga conectada superior a 36 kW
- Medir demanda
- Facturación mensual

Independientemente de lo anterior, los programas de facturación emiten un aviso para que se instale un medidor de demanda máxima cuando el consumo sea superior a 14, 000 kWh mensuales.

TARIFA 3
SERVICIOS GENERALES (mayores a 25 kW)

Esta tarifa se aplica a todos los servicios que destinen la energía en baja tensión a cualquier uso, con demanda de más de 25 kW, excepto a los servicios para los cuales se fija específicamente su tarifa.

CUOTAS APLICABLES. Cargo por demanda máxima y cargo por energía consumida.

Cargo por demanda	Cargo por KWH
N$ 41.95239	N$ 0.20861

DEMANDA POR CONTRATAR: la fija inicialmente el usuario; su valor no será menor al 60 % de la carga total conectada, ni menor de 25 kW o de la capacidad del mayor motor o aparato instalado.

TARIFA 5 Y 5A
ALUMBRADO PUBLICO

Esta tarifa sólo se aplica al suministro de energía eléctrica para el servicio de semáforos, alumbrado y alumbrado ornamental por temporadas, de calles, plazas, parques y jardines públicos. La tarifa 5 se aplica únicamente para las zonas conurbanas de méxico, D.F., Monterrey y Guadalajara. La tarifa 5A se aplica para el resto del país.

CUOTAS APLICABLES MENSUALMENTE. Cargos por energía consumida en alta tensión y en baja tensión.

Tarifa	Alta tensión	Baja tensión
5	N$ 0.41076	N$ 0.48932
5A	N$ 0.30807	N$ 0.36701

DEMANDA POR CONTRATAR. la demanda por contratar corresponde al 100 % de la demanda conectada.

TARIFA 6
BOMBEO DE AGUAS

Esta tarifa se aplica al suministro de energía eléctrica para servicio público de bombeo de aguas potables o negras.

CUOTAS APLICABLES. Cargo fijo. Independientemente de la energía consumida y cargo por energía consumida.

Cargo fijo	Cargo por KWH
N$ 42.15657	N$ 0.23338

DEMANDA POR CONTRATAR. La demanda por contratar la fija inicialmente el usuario, no será menor del 60 % de la carga total conectada ni menor de la capacidad del mayor motor o aparato instalado.

TARIFA 7
SERVICIO TEMPORAL

Esta tarifa se aplica a todos los servicios que destinen la energía temporalmente a cualquier uso, exclusivamente donde y cuando la capacidad de las instalaciones del suministrador lo permitan y éste tenga líneas de distribución adecuadas par dar el servicio.

HORARIO. El convenio en cada caso entre el suministrador y el usuario, el que no debe hacer uso del servicio fuera del horario estipulado.

CUOTAS APLICABLES. Cargo por demanda y cargo por energía consumida.

Cargo por demanda	Cargo por KWH
N$ 26.34582	N$ 0.65874

a) N$ 0.29000 por el primer día de servicio
b) N$ 0.03600 por cada día adicional de servicio
c) N$ 0.72000 por cada kW de demanda
d) N$ 0.01800 por cada kW consumido

En los casos de personas o negociaciones que se dediquen a usar aparatos eléctricos portátiles tales como máquinas de pulir,encerar y lavar pisos, pintar, soldar, etc., el suministrador podrá optar por aplicar las cuotas de los incisos a) o b), o bien, N$ 1.43500 por cada kW de demanda.

TARIFA 9
SERVICIO TEMPORAL

Esta tarifa se aplica exclusivamente a los servicios en alta o baja tensión que destinen la energía para el bombeo de agua utilizada en el riego de tierras dedicadas al cultivo de productos agrícolas y al alumbrado del local donde se encuentre instalado el equipo de bombeo.

CUOTAS APLICABLES MENSUALMENTE. Cargos por la energía consumida

N$ 0.00205 por cada uno de los primeros 5,000 kWh
N$ 0.00245 por cada uno de los siguientes 10,000 kWh
N$ 0.00270 por cada uno de los siguientes 20,000 kWh
n$ 0.00300 por cada kWh adicional a los anteriores.

TENSION Y CAPACIDAD DE SUMINISTRO. El suministrador sólo está obligado a proporcionar el servicio a la tensión y capacidad disponibles en el punto de entrega.

DEMANDA POR CONTRATAR. La demanda por contratar la fijará inicialmente el usuario con base en sus necesidades de potencia. Cualquier fracción de kW, se tomará como kW completo.

DEPOSITO DE GARANTIA. N$ 0.09500 por cada kW de demanda contratada.

EJEMPLOS DE DETERMINACION DE LA DEMANDA POR CONTRATAR

1. Un posible usuario solicita servicio en baja tensión con la siguiente carga conectada:
   * Alumbrado
   - 12 lámparas fluorescentes de 110 watts, c/u 1,584 Watts
   ** Fuerza
   - Un motor trifásico de 12 hp 7,161 Watts
   Otras
   - Un calefactor 1,000 Watts
   Total 9,745 Watts

(*) Se considera el 20 % adicional por el equipo auxiliar, en este caso las balastras.
(**) Se considera un motor con el 80 % de eficiencia

DEMANDA A CONTRATAR. Supongamos que el usuario contrata una demanda de 6 kilowatts, en este caso debemos considerar que existe conectado un motor de 7,161 watts, por lo cual debemos orientar al usuario a fin que de acuerdo a sus necesidades reales de potencia, contrate una demanda no menor a 8 kilowatts. El servicio será en tarifa 2.

2. Un posible usuario solicita servicio en baja tensión con las siguientes cargas conectadas:
   * Alumbrado
   - 50 lámparas fluorescentes de 75 watts c/u 4,687.5 W
   - 100 lámparas incandescentes de 150 watts c/u 15,000 W

   * Fuerza
   - 5 motores de 5 hp c/u 22,450 W
   - 1 motor de 10 hp 8,674 w

Total 50,811.5 W

En este caso puede existir incertidumbre acerca del valor de la demanda por contratar, ya que si el usuario solicita una demanda de 21 kilowatts, también es cierto que tal valor puede rebasar los 25 kilowatts. En el primer supuesto sería contratar el servicio bajo tarifa 2, mientras que en el segundo sería tarifa 3. Tampoco podría predecirse cual de las dos tarifas resultaría más económica para el usuario, puesto que se desconoce el factor de carga del servicio, por lo tanto, la solución sería contratar en tarifa 2 con 21 kilowatts de demanda, instalando en este caso equipo de medición de demanda, facturando mensualmente y vigilando que en el caso que la demanda exceda en tres veces consecutivas 25 kilowatts, se reclasifique el servicio en tarifa 3.

APLICACION DE LAS TARIFAS O-M A I-30
Conceptos sobre los períodos punta y base

PERIODO DE PUNTA. Es el tiempo comprendido entre las 18:00 y las 22:00 horas, de lunes a sábado. A excepción de las regiones de Baja California, Baja California Sur y Noroeste, para las cuales y durante los meses de junio a octubre será el tiempo comprendido entre las 16:00 a las 22:00 horas.

Los días de descanso obligatorio, establecidos en el artículo 74 de la Ley Federal del Trabajo, así como los que se establezcan por Acuerdo presidencial, se exceptúan de esta consideración.

PERIODO DE BASE. Es el resto de las horas del mes, no comprendidas en el Período de Punta.

ENERGIA DE PUNTA. Es la energía consumida durante el período de punta.

ENERGIA DE BASE. Es la energía consumida durante el período de base.
Estos dos conceptos se aplican únicamente para las tarifas H-M, H-S y H-T.

Conceptos sobre la demanda

DEMANDA MEDIA. Esa la demanda de energía eléctrica promedio en un período determinado.

DEMANDA MAXIMA MEDIDA. la demanda máxima medida se determina mensualmente por medio de instrumentos de medición que indiquen la demanda media en kilowatts durante cualquier intervalo de 15 minutos, en el cual el consumo de energía eléctrica sea mayor que en cualquier otro intervalo de 15 minutos en el período de facturación.

DEMANDA MAXIMA MEDIDA EN PERIODO DE PUNTA. Se determina mensualmente durante cualquier intervalo de 15 minutos del Período de Punta,en el cual el consumo de energía eléctrica del consumidor sea mayor que en cualquier otro intervalo de 15 minutos en el Período de Punta.

DEMANDA MAXIMA MEDIDA EN PERIODO DE BASE. Se determina mensualmente durante cualquier intervalo de 15 minutos del Período de Base, en el cual el consumo de energía eléctrica del consumidor sea mayor que en cualquier otro intervalo de 15 minutos en

PERFIL DE CARGA

DEMANDA MAXIMA, DEMANDA MEDIA, FACTOR DE CARGA Y CONSUMO PROMEDIO

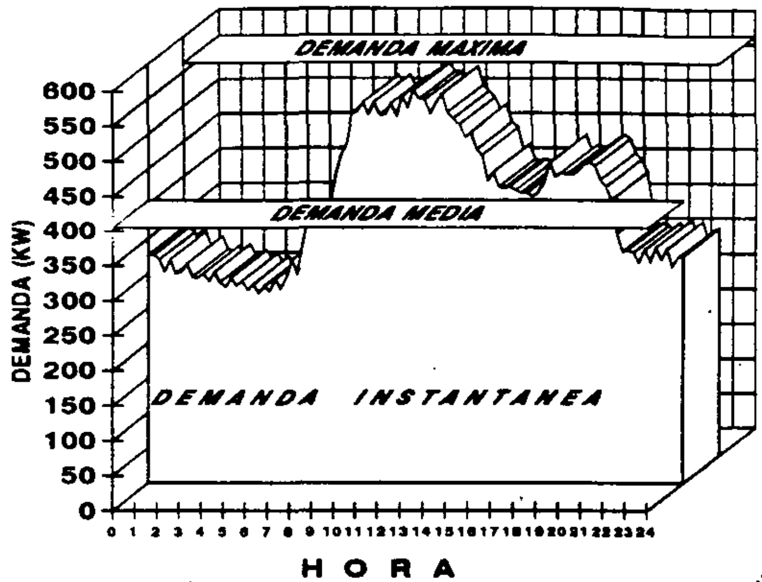
DATOS DEL PERFIL :

DEMANDA INSTANTANEA.
Es el valor de demanda (KW) registrado a cada instante durante un período determinado.

DEMANDA MAXIMA:
Es el valor máximo de demanda instantánea (KW) registrado a lo largo de determinado período.

DEMANDA MEDIA:
Es el valor promedio de todas las lecturas instantáneas registradas en un período determinado.

FACTOR DE CARGA.
Es la relación entre la demanda media (KW) y la demanda máxima (KW) en determinado período. Se puede expresar en porunidad o en porciento.



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CONCEPTOS SOBRE LOS PERIODOS PUNTA Y BASE

PERIODO DE PUNTA.
Es el tiempo comprendido entre las 18:00 y las 22:00 horas, de lunes a sábado. Se exceptúan las regiones de B.C., B.C. Sur y Noroeste, para las cuales y durante los meses de junio a octubre será el tiempo comprendido entre las 16:00 y las 22:00 horas.

Los días de descanso obligatorio, establecidos en el Artículo 74 de la Ley Federal del Trabajo así como los que se establezcan por Acuerdo Presidencial, se exceptúan de esta consideración.

DEMANDA MAXIMA MEDIDA EN PUNTA
Se determina mensualmente durante cualquier intervalo de 15 minutos en el Periodo de Punta, en el cual el consumo de energía sea mayor que en cualquier otro intervalo de 15 minutos en el Periodo de Punta.

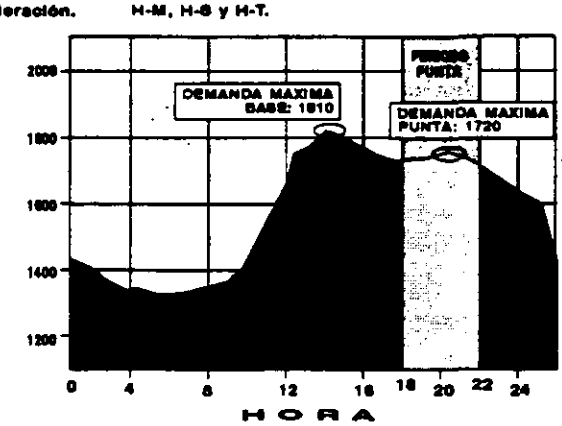
DEMANDA MAXIMA MEDIDA EN BASE
Se determina cada mes durante cualquier intervalo de 15 minutos del periodo de Base, en el cual el consumo de energía eléctrica sea mayor que en cualquier otro intervalo de 15 minutos en el periodo de Base.

PERIODO DE BASE
Es el resto de las horas del mes, no comprendidas en el periodo de punta.

ENERGIA DE PUNTA
Es la energía consumida durante el periodo de punta.

ENERGIA DE BASE
Es la energía consumida durante el periodo de base. Estos dos conceptos se aplican únicamente para las tarifas H-M, H-S y H-T.

DEMANDA MAXIMA MEDIDA
Se determina mensualmente por medio de instrumentos que indiquen la demanda media en kilowatts durante cualquier intervalo de 15 minutos, en el cual el consumo de energía eléctrica sea mayor que en cualquier otro intervalo de 15 minutos en el periodo de facturación.



DIFERENCIA DE DEMANDAS
Es la Demanda Máxima en Base menos la Demanda Máxima en Punta, cuando esta diferencia sea positiva. Cuando la Demanda Máxima en Punta sea mayor que la Demanda Máxima en Base, la Diferencia de Demandas es cero.

AGRR/ABR-93

el Período de Base.

DIFERENCIA DE DEMANDAS. Es la Demanda Máxima Medida en período de Base manos Demanda medida en período de Punta, cuando esta diferencia sea positiva. En aquellos casos en que la Demanda máxima Medida en Período de Punta sea superior a la Demanda Máxima Medida en Período de Base, la Diferencia de Demandas es igual a cero.

Conceptos sobre la demanda y energía facturables

DEMANDA FACTURABLE. Es el resultado de sumar la Demanda Máxima Medida en Período de Punta y la quinta parte de la diferencia de demandas.

Este concepto se aplica para las tarifas H-M, H-S, H-T y H-TL.

ENERGIA FACTURABLE DE PUNTA. Es el máximo entre la energía consumida durante el Período de Punta y el 80% del producto de la Demanda Máxima Medida en Período de Punta por el número de horas del Período de Punta.

ENERGIA FACTURABLE DE BASE. Es la diferencia entre la Energía Total Consumida durante el mes y la Energía Facturable de Punta.

Estos dos conceptos se aplican únicamente para las tarifas H-SL y H-TL.

Cuotas y condiciones

TARIFA O-M
TARIFA ORDINARIA PARA SERVICIO GENERAL EN MEDIA TENSION CON DEMANDA MENOR A 1, 000 KW.

Esta tarifa se aplicará a los servicios que destinen la energía en media tensión a cualquier uso, con demanda menor a 1, 000 kW.

CUOTAS APLICABLES MENSUALMENTE.

Cargo por kW de demanda máxima medida N$ 23.086
cargo por kWh de energía consumida N$ 0.13565

MINIMO MENSUAL. El importe que resulte de aplicar 10 veces el cargo por kilowatt de demanda máxima medida.

DEMANDA POR CONTRATAR. La demanda por contratar la fijará inicialmente el usuario; su valor no será menor del 60% de la carga total conectada, ni menor de 20 kilowatts o de la capacidad del mayor motor o aparato instalado.

En el caso de que el 60% de la carga total conectada exceda la capacidad de la subestación del usuario, se tomará como demanda contratada la capacidad de dicha subestación a un factor de 85%. Si la demanda por contratar es mayor de 1, 000 kilowatts, el usuario debe solicitar al suministrador que aplique la Tarifa H-M.

Cualquier fracción de kilowatt se tomará como kilowatt completo.

DEPOSITO DE GARANTIA. Dos veces el importe que resulte de aplicar el cargo por demanda máxima medida a la demanda contratada.

TARIFA H-M.

TARIFA HORARIA PARA SERVICIO GENERAL EN MEDIA TENSION, CON DEMANDA DE 1, 000 KW O MAS

Esta Tarifa se aplicará a los servicios que destinen la energía en media tensión a cualquier uso, con una demanda de 1, 000 kilowatts o más.

CUOTAS APLICABLES MENSUALMENTE.

Cargo por KW de demanda facturable	N$ 23.432
Cargo por KWh de energía de punta	N$ 0.19534
Cargo por KWh de energía de base	N$ 0.12209

MINIMO MENSUAL. El importe que resulte de aplicar 10 veces el cargo por kilowatt de demanda facturable. En el caso de que el 60% de la carga total conectada exceda la capacidad de la subestación del usuario, sólo se tomara como demanda contratada la capacidad de dicha subestación a un factor de 85%.

Cualquier fracción de kilowatt se tomará como kilowatt completo.

Cuando el usuario mantenga durante 6 meses consecutivos, tanto una demanda máxima medida en Período de Punta, como una demanda Máxima Medida en Período de Base inferiores a 1, 000 kilowatts, podrá solicitar al suministrador su incorporación a la Tarifa O-M. Cualquier fracción de kilowatt se tomará como kilowatt completo.

HORARIO. Para los efectos de la aplicación de esta tarifa, se utilizará el horario oficial que rige en el territorio nacional, por decreto presidencial publicado en el diario oficial de la federación el 24 de abril de 1942.

DEPOSITO DE GARANTIA. Dos veces el importe que resulte de aplicar el cargo por demanda facturable a la demanda contratada.

TARIFA H-S

TARIFA HORARIA PARA SERVICIO GENERAL EN ALTA TENSION, NIVEL SUBTRANSMISION

Esta tarifa se aplicará a los servicios que destinen la energía a cualquier uso, suministrado en alta tensión, nivel subtransmisión.

CUOTAS APLICABLES MENSUALMENTE.

Cargo por KW de demanda facturable	N$ 26.441
Cargo por KWh de energía de punta	N$ 0.17242
Cargo por KWh de energía de base	N$ 0.09597

MINIMO MENSUAL. El importe que resulte de aplicar veinte veces el cargo por kilowatt de demanda facturable.

DEMANDA POR CONTRATAR. La demanda por contratar la fijará inicialmente el usuario; su valor no será menor del 60% de la carga total conectada, ni menor de la capacidad del mayor aparato instalado.

En el caso que el 60% de la carga total conectada exceda la capacidad de la subestación del usuario, sólo se tomará como demanda contratada la capacidad de dicha subestación a un factor de 85%.

Cualquier fracción de kilowatt se tomará como kilowatt completo.

HORARIO. Idem Tarifa H-M.

DEPOSITO DE GARANTIA. Idem Tarifa H-M.

TARIFA H-T

TARIFA HORARIA PARA SERVICIO GENERAL EN ALTA TENSION, NIVEL TRANSMISION.

Esta tarifa se aplicará a los servicios que destinen la energía a cualquier uso, suministrados en alta tensión, nivel transmisión.

CUOTAS APLICABLES MENSUALMENTE.

Cargo por KW de demanda de energía facturable	N$ 24.459
Cargo por KWh de energía de punta	N$ 0.16196
Cargo por KWh de energía de base	N$ 0.08987

MINIMO MENSUAL. Idem Tarifa H-S.

DEMANDA POR CONTRATAR. Idem Tarifa H-S.

HORARIO. Idem Tarifa H-M.

DEPOSITO DE GARANTIA. Idem Tarifa H-M.

TARIFA H-SL

TARIFA HORARIA PARA SERVICIO GENERAL EN ALTA TENSION, NIVEL SUBTRANSMISION, PARA LARGA UTILIZACION.

Esta tarifa se aplicará a los servicios que destinen la energía a cualquier uso, suministrados en alta tensión, nivel subtransmisión, y que por las características de utilización de su demanda soliciten inscribirse en este servicio.

CUOTAS APLICABLES MENSUALMENTE. Cargos por la demanda facturable, por la energía facturable de punta y por la energía facturable de base.

Cargo por KW de demanda facturable	N$ 26.441
Cargo por KWh de energía facturable de punta	N$ 0.27885
Cargo por KWh de energía facturable de base	N$ 0.07490

MINIMO MENSUAL. Idem Tarifa H-S.

DEMANDA POR CONTRATAR. Idem Tarifa H-S.

DEPOSITO DE GARANTIA. Idem Tarifa H-M.

TARIFA H-TL

TARIFA HORARIA PARA SERVICIO GENERAL EN ALTA TENSION, NIVEL TRANSMISION, PARA LARGA UTILIZACION.

Esta tarifa se aplicará a los servicios que destinen la energía a cualquier uso, suministrados en alta tensión, nivel transmisión, y que por las características de utilización de su demanda soliciten inscribirse en este servicio.

CUOTAS APLICABLES MENSUALMENTE. Se aplicarán los siguientes cargos por la demanda facturable, por la energía facturable de punta y por la energía facturable de base.

Cargo por KW de demanda facturable	N$ 24.459
Cargo por KWh de energía de punta	N$ 0.20754
Cargo por KWh de energía de base	N$ 0.07281

MINIMO MENSUAL. Idem Tarifa H-S.

DEMANDA POR CONTRATAR. Idem Tarifa H-S.

DEPOSITO DE GARANTIA. Idem Tarifa H-M.

TARIFA I-30
TARIFA PARA SERVICIO INTERRUMPIBLE.

Esta tarifa será aplicable a los usuarios de las tarifas H-S, H-T, H-SL y H-TL que soliciten inscribirse adicionalmente en este servicio y que tengan una Demanda Máxima Medida en el Período de Punta o Base, mayor o igual a 20,000 kW durante los tres meses previos a la solicitud de inscripción.

DEMANDA INTERRUMPIBLE CONTRATADA Y DEMANDA FIRME CONTRATADA. El usuario que solicite servicio en esta tarifa deberá contratar una demanda interrumpible y una demanda firme. La demanda firme contratada no puede ser menor al 30% del promedio de su Demanda Máxima Medida en el Período de Punta durante los últimos tres meses previos a su solicitud de inscripción. La demanda interrumpible contratada no puede ser menor a 7,000 kW ni mayor al 70% del promedio de su Demanda Máxima Medida en Período de Punta y durante los tres meses previos a su solicitud de inscripción.

BONIFICACION MENSUAL

Para los usuarios de tarifas H-T y H-TL	N$ 4.988	por cada kW de demanda interrumpible bonificable
Para los usuarios de tarifas H-S y H-SL	N$ 5.237	por cada kW de demanda interrumpible bonificable

La bonificación mensual será aplicada en la facturación del usuario calculada de acuerdo con la tarifa aplicable.

DEMANDA INTERRUMPIBLE BONIFICABLE. La Demanda Interrumpible Bonificable mensualmente será kW mínimos entre la Demanda Interrumpible Contratada y el resultado de restar a la Demanda Máxima Medida en Período de Punta la Demanda Firme Contratada. En caso inferior a la Demanda Firme Contratada, la Demanda Interrumpible Bonificada será cero.

CONDICIONES GENERALES DE LA INTERRUPCION. El suministrador podrá solicitar al usuario la suspensión total o parcial de la demanda contratada como interrumpible con la anticipación de 30 minutos como mínimo en la forma convenida con el usuario.

DE LA DURACION Y PERIODICIDAD DE LAS INTERRUPCIONES. El suministrador podrá solicitar la interrupción una vez en un día por período hasta de 4 horas. El total de interrupciones acumuladas en un año calendario será como máximo de 14. Las interrupciones que no hayan sido utilizadas por el suministrador no podrán ser acumuladas para el siguiente año calendario.

CARGOS POR INCUMPLIMIENTO. Si el suministrador determina mediante los registros de medición de la demanda del usuario, que éste no cumplió o cumplió parcialmente con una solicitud de interrupción, tendrá derecho a aplicar en la facturación un cargo equivalente a 6 veces el monto de la bonoficación mensual correspondiente a la demanda interrumpible no proporcionada. Si dentro de un período de 12 meses, el usuario incurre en reincidencia, el suministrador, en adición a la penalización anterior, podrá a su discreción de servicio interrumpible. La demanda interrumpible no proporcionada será la diferencia entre:

i) El resultado de restar a la Demanda Máxima Medida durante el lapso de interrupción la Demanda Firme y Contratada y
ii) El resultado de restar a la Demanda Interrumpible Contratada la Demanda Interrumpible Solicitada.

Cargos por Mantenimiento

A todas las tarifas descritas se les aplicará un cargo adicional mensual por mantenimiento como indica la Tabla 3.

MONTO DEL CARGO MENSUAL POR MANTENIMIENTO A PARTIR DEL 12 DE NOVIEMBRE DE 1991

TARIFAS DOMESTICAS

0 a 25 kWH	N$ 3.60
26 50	4.20
51 75	4.80
76 100	4.80
101 200	6.01
más de 200	9.01
TARIFA 2	5.45
3	9.10
5 Y 5A	9.10
6	Exenta
7	9.10
9	3.00
O-M	9.10
H-M	9.10
H-S	9.10
H-T	9.10

TABLA 3

Cargos y Bonificaciones Relacionados con el Factor de Potencia

FORMULA Y GRAFICA DE CARGOS:

Porcentaje de Recargo = 3/5 x ((90/FP) - 1) x 100 para un FP menor que 90%

FORMULA DE BONIFICACION:

Porcentaje de Bonificación = 1/4 x (1 - (90/FP)) x 100 FP mayor al 90%

Donde FP es el Factor de Potencia expresado en por ciento.

Los valores resultantes de la aplicación de estas fórmulas se redondearán a un solo decimal, por defecto o por exceso, según sea o no menor que 5 el segundo decimal. En ningún caso se aplicarán porcentajes de recargo superiores a 120%, ni porcentajes de bonificación superiores a 2.5%.

Ajuste Paulatino de las Tarifas 1 a 9

A partir del 22 de Octubre de 1992 entra en vigor el ajuste paulatino de incremento en las tarifas eléctricas de acuerdo a las disposiciones siguientes:

Sobre las cuotas de las tarifas para el servicio doméstico (1, 1A, 1B, 1C y 1D) se aplicará un factor de 1.0057 mensual acumulativo a excepción de aquellas consignadas en la siguiente disposición:

Se aplicará un factor de 1.0079 mensual acumulativo a las cuotas para consumos mensuales superiores a 200 kWh en la tarifa 1; 250 kWh en la tarifa 1A; 300 kWh en la tarifa 1B; 750 kWh en la tarifa 1C; y 1000 kWh en la tarifa 1D.

Se aplicará un factor de 1.0079 mensual acumulativo a las cuotas de las tarifas 2, 3 y 7.

Se mantiene el factor de 1.03 mensual acumulativo a las cuotas de la tarifa 9.

Disposición que establece el procedimiento para el ajuste automático en las tarifas 2, 3 y 7 de manera que se reflejen las fluctuaciones de los precios internos de los combustibles, cualquiera que sea el sentido de las mismas. El suministrador aplicará dicha disposición complementaria a partir del 22 de octubre de 1992.

Ajuste por Variación de Combustible

CLAUSULA DE LOS AJUSTES DE LA FACTURACION DE LA ENERGIA POR VARIACION EN LOS PRECIOS DE LOS COMBUSTIBLES

10 bis. 1. APLICACION DE LOS AJUSTES

Esta cláusula de los ajustes se aplicará a la facturación de la energía consumida en las tarifas O-M, H-M, H-S, H-T, H-TL para reflejar las variaciones de los precios y de los combustibles utilizados en la generación de energía eléctrica.

10 bis 2. CALCULO DE LOS AJUSTES

Para cada mes calendario el monto de los ajustes -expresados en pesos-, se calcularán multiplicando el total de energía consumida en dicho mes -expresado en kWh-, por los factores mensuales de ajuste que se expresan en pesos/kWh.

10 bis 3. FACTORES DE AJUSTE

Los factores de ajuste del mes calendario se calcularán mediante la siguiente fórmula por cada nivel de tensión de suministro:

Factores de ajuste

Donde:

(j) Expresa cada uno de los 4 niveles de tensión de suministro: 1) Alta Tensión Nivel Transmisión (tarifas H-T y H-TL); 2) Alta Tensión Nivel Subtransmisión (tarifas H-S y H-SL); 3) Media Tensión (tarifas O-M y H-M) y 4) Baja Tensión (tarifas 2, 3 y 7).

(i) Expresa cada uno de los 5 combustibles que se someten al ajuste mensual: 1) Combustóleo importado, cotización Pemex, puesto en Manzanillo; 2) Combustóleo nacional,cotización Pemex, centro productor; 3) Gas natural, cotización Pemex, zona centro; 4) Diesel no. 1. Cotización Pemex, única a nivel nacional; 5) Carbón, cotización MICARE que incluye manejo de cenizas, única a nivel nacional.

(PBi) Expresa el precio base -sin IVA- para cada combustible.

(Pi) Es el precio -también sin IVA- para cada combustible, vigente en la quincena anterior al mes calendario del cálculo del monto del ajuste.

(ai) Corresponde a los coeficientes de ajuste para cada combustible.

FTj Representa un factor aplicable a cada uno de los cuatro niveles de tensión de suministro.

j	Tarifa	Tensión	FT
1	H-T y H-TL	Alta, nivel transmisión	1.029
2	H-S y H- SL	Alta, nivel subtransmisión	1.042
3	O-My H-M	Media	1.067
4	2, 3 y 7	Baja	1.104

i	Combustible	PB	a
1	Combustóleo importado	0.23403 N$/l	0.031744
2	Combustóleo nacional	0.19391 N$/l	0.104201
3	Gas natural	0.18410 N$/m	0.44212
4	Diesel no. 1	0.49130 N$/l	0.003048
5	Carbón	0.10041 N$/kg	0.038062

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FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

TEMA 2

TERMINOLOGIA, SIMBOLOGIA Y UNIDADES.

ING. ALEX RAMIREZ RIVERO.

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TEMA 2

TERMINOLOGIA Y UNIDADES DE ILUMINACION.

En Luminotecnia intervienen dos elementos básicos a considerar: la fuente productora de luz y el objeto a iluminar. Las unidades y magnitudes fundamentales empleadas para valorar y comparar las cualidades y los efectos de las fuentes de luz son las siguientes:

FLUJO LUMINOSO (POTENCIA LUMINOSA)
RENDIMIENTO LUMINOSO (EFICACIA)
CANTIDAD DE LUZ (ENERGIA LUMINOSA)
INTENSIDAD LUMINOSA
ILUMINANCIA
LUMINANCIA

A continuación describiremos brevemente cada uno de los anteriores conceptos.

IV.1.- FLUJO LUMINOSO

La energía transformada por los manantiales luminosos no se puede aprovechar totalmente para la producción de luz. Por ejemplo, una lámpara incandescente consume una determinada energía eléctrica que se transforma en energía radiante, de la cual sólo una pequeña parte es percibida por el ojo en forma de luz, mientras que el resto se pierde en calor.

A la energía radiante de una fuente de luz que produce una sensación luminosa se le llama Flujo Luminoso o Potencia Luminosa. El flujo luminoso se representa por la letra griega ϕ y su unidad es el LUMEN (lm). Un lumen es el flujo luminoso de la radiación monocromática que se caracteriza por una frecuencia f de valor 540 x 10E12 Hertz y por un flujo de energía radiante equivalente a 1/683 watts. Un watt de energía radiante de longitud de onda de 555 nm en el aire equivale a 683 lm aproximadamente.

La medida del flujo luminoso se realiza en laboratorio por medio de un fotoelemento ajustado según la curva de sensibilidad fotópica del ojo a las radiaciones monocromáticas, incorporado a una esfera hueca a la cual se le da el nombre de esfera integradora de Ulbricht, y en cuyo interior se coloca la fuente a medir.

En la Tabla siguiente se muestran algunas de las lámparas más usadas y su flujo luminoso característico:

Tipo de Lámpara	Flujo luminoso lm
Efluvios	0.6
Vela de cera	10
Bicicleta	18
Incandescente Standar de 100 W	1 380
Fluorescente L 40 W/20 (Blanco frío)	3 200
Mercurio a alta presión HQL 400 W	23 000
Halogenuros metálicos HQI 400 W	28 000
Sodio a alta presión NAV-T 400 W	48 000
Sodio a baja presión NA 180 W	33 000
Magnesio AG 3B	450 000

TABLA I.- FLUJO LUMINOSO DE LAMPARAS COMUNES

IV.2.- EFICACIA O RENDIMIENTO LUMINOSO.

El rendimiento luminoso o eficacia luminosa de una fuente de luz, indica el flujo que emite la misma por cada unidad de potencia eléctrica consumida para su obtención.

El rendimiento o eficacia se representa por la letra griega ETA (η) y sus unidades son lúmenes por watt (lm/w):

$$\eta = \frac{\phi\ [lm]}{W\ [watt]}$$

Si se lograse fabricar una lámpara que transformara sin pérdidas toda la potencia eléctrica consumida en luz de una longitud de onda de 555 nm, esta lámpara tendría el mayor rendimiento posible, cuyo valor sería de 683 lm/w, pero como sólo una pequeña parte es transformada en luz, los rendimientos luminosos obtenidos hasta ahora para las distintas lámparas quedan muy abajo de este valor, presentando diferencias notables entre las mismas, como puede apreciarse en la Tabla II.

Por ejemplo, una lámpara incandescente estándar de 40 watts produce 440 lúmenes, por lo que tiene una eficacia de 11 lm/w. Una lámpara de sodio baja presión de 180 watts produce en cambio 3294 lúmenes por lo que tiene una eficacia de 183 lm/w.

FACULTAD DE INGENIERIA U.N.A.M.
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TEMA 2

TERMINOLOGIA, SIMBOLOGIA Y UNIDADES.

ING. ALEX RAMIREZ RIVERO.

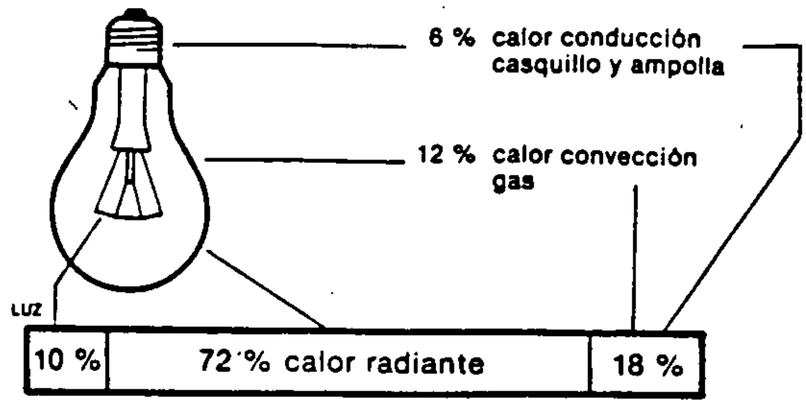
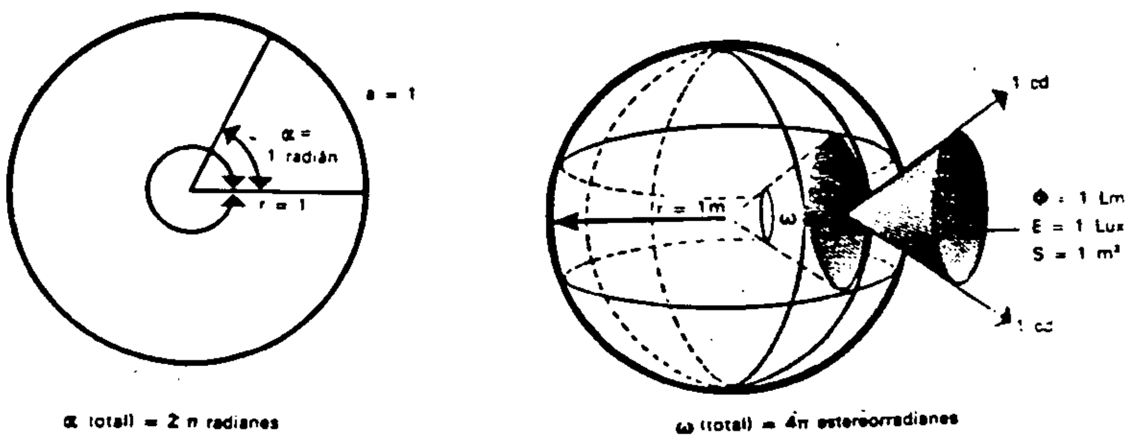


FIG. 1.- TRANSFORMACION DE ENERGIA ELECTRICA PARA LA PRODUCCION DE LUZ EN UNA LAMPARA INCANDESCENTE.



FIGS. 2 y 3.- ANGULO PLANO, ANGULO SOLIDO Y RELACION ENTRE FLUJO LUMINOSO, INTENSIDAD LUMINOSA E ILUMINANCIA.

TEMA 2

TERMINOLOGIA Y UNIDADES DE ILUMINACION.

En Luminotecnia intervienen dos elementos básicos a considerar: la fuente productora de luz y el objeto a iluminar. Las unidades y magnitudes fundamentales empleadas para valorar y comparar las cualidades y los efectos de las fuentes de luz son las siguientes:

FLUJO LUMINOSO (POTENCIA LUMINOSA)
RENDIMIENTO LUMINOSO (EFICACIA)
CANTIDAD DE LUZ (ENERGIA LUMINOSA)
INTENSIDAD LUMINOSA
ILUMINANCIA
LUMINANCIA

A continuación describiremos brevemente cada uno de los anteriores conceptos.

IV.1.- FLUJO LUMINOSO

La energía transformada por los manantiales luminosos no se puede aprovechar totalmente para la producción de luz. Por ejemplo, una lámpara incandescente consume una determinada energía eléctrica que se transforma en energía radiante, de la cual sólo una pequeña parte es percibida por el ojo en forma de luz, mientras que el resto se pierde en calor.

A la energía radiante de una fuente de luz que produce una sensación luminosa se le llama Flujo Luminoso o Potencia Luminosa. El flujo luminoso se representa por la letra griega ϕ y su unidad es el LUMEN (lm). Un lumen es el flujo luminoso de la radiación monocromática que se caracteriza por una frecuencia f de valor 540 x 10E12 Hertz y por un flujo de energía radiante equivalente a 1/683 watts. Un watt de energía radiante de longitud de onda de 555 nm en el aire equivale a 683 lm aproximadamente.

La medida del flujo luminoso se realiza en laboratorio por medio de un fotoelemento ajustado según la curva de sensibilidad fotópica del ojo a las radiaciones monocromáticas, incorporado a una esfera hueca a la cual se le da el nombre de esfera integradora de Ulbricht, y en cuyo interior se coloca la fuente a medir.

En la Tabla siguiente se muestran algunas de las lámparas más usadas y su flujo luminoso característico:

superficie luminosa más o menos grande, cuya intensidad de radiación se ve afectada por la propia construcción de la fuente presentando valores diferentes en las distintas direcciones.

Con aparatos especiales se puede determinar la intensidad luminosa de un manantial en todas direcciones del espacio con relación a un eje vertical. Si representásemos por medio de vectores la intensidad luminosa de un manantial en infinitas direcciones del espacio, obtendríamos un cuerpo llamado Sólido Fotométrico.

Haciendo pasar un plano por el eje de simetría del cuerpo luminosos se obtendría una sección limitada por una curva que se denomina Curva de Distribución Luminosa o Curva Fotométrica. Mediante la curva fotométrica de un manantial se puede determinar con exactitud la intensidad luminosa en cualquier dirección, dato ncesario para los cálculos de iluminación.

Las curvas fotométricas se dan referidas a un flujo luminoso de 1000 lúmenes y, como el caso general es que la fuente de luz emita un flujo mayor, los valores de intensidad luminosa correspondientes se encuentran mediante una simple relación.

Por ejemplo, si una lámpara de mercurio de alta presión tiene un flujo luminoso de 23000 lúmenes, los valores de la intensidad luminosa deducidos de su curva fotométrica dada para 1000 lúmenes, habrá que multiplicarlos por el factor 23 hallado de la relación 23000/1000, para obtener el verdadero valor.

IV.6.- MEDIDA DE LA INTENSIDAD LUMINOSA.

La medida de la intensidad luminosa se realiza en el laboratorio por medio de aparatos especiales, de los cuales existen diversos modelos fundados en la ley Inversa del Cuadrado de la Distancia -la cual se discutirá posteriormente- usando una luz patrón y otra desconocida, situadas una frente a otra en un mismo eje e interceptadas en una pantalla en la que se igualan las iluminaciones captadas en ambas caras de la misma mediante un objetivo apropiado.

En las figuras 5, 6 y 7 se muestran las curvas fotométricas típicas de algunas de las lámparas más utilizadas.

IV.7.- ILUMINANCIA

La iluminancia o iluminación de una superficie es la relación entre el flujo luminosos que

Tipo de Lámpara	Potencia nominal W	Rendimiento luminoso lm/W
Efluvios	0.3	2
Incandescente Standar 40 W/220 V	40	11
Fluorescente L 40 W/20 (Blanco frío) .	40	80
Mercurio a alta presión HQL 400 W	400	50
Halogenuros metálicos HQI 400 W	360	78
Sodio a alta presión NAV-T 400 W	400	120
Sodio a baja presión NA 180 W	180	183

TABLA II.- EFICACIAS PROMEDIO DE DISTINTAS LAMPARAS

Cabe aclarar que las eficacias de la Tabla II se refieren exclusivamente a las lámparas; para las lámparas de descarga como sistema completo incluyendo instalación y accesorios de conexión dichas eficacias pueden variar sustancialmente.

IV.3.- ENERGIA LUMINOSA O CANTIDA DE LUZ.

De forma análoga a la energía eléctrica que se determina por la potencia eléctrica por unidad de tiempo, la cantidad de luz o energía luminosa se determina por la potencia luminosa o flujo luminoso por unidad de tiempo.

La cantidad de luz se representa por la letra Q y su unidad es el LUMEN-HORA (lm-h).

Su fórmula es:

$$Q = \phi \times t$$

Esta magnitud es importante en las lámparas de relámpago empleadas en fotografía, pues su valor es decisivo para la iluminación de la película. Debido al corto tiempo de la descarga, la cantidad de luz suele darse en lúmenes por segundo (lms). En la lámpara que emite una cantidad de luz de 2.1 lmh, esta magnitud por segundo será 2.1 lmh x 3600 seg ó 7560 lms.

También tiene interés conocer a efectos de cálculos económicos la cantidad de luz que emite una lámpara durante su vida. Una lámpara incandescente de 40 watts que emite un flujo recibe la superficie y su extensión. Se representa por la letra E y su unidad es el LUX en el Sistema Internacional de Unidades. Su ecuación es:

$$E = \frac{\phi}{A}$$

De esta ecuación se deduce que en cuanto mayor sea el flujo luminoso incidente sobre una superficie, mayor será la iluminación, y que, para un mismo flujo luminoso incidente, la iluminación será tanto mayor en la medida en que disminuya la superficie.

El lux, unidad de iluminancia se define como la iluminación de una superficie de un metro cuadrado que recibe uniformemente repartido un flujo luminoso de un lumen (Fig. 8).

$$LUX = \frac{1\ lm}{1\ m^2}$$

La iluminancia constituye un dato importante para valorar el nivel de iluminación que existe en una oficina, en la superficie de un recinto, en una calle, etc.

La medida de iluminancia se realiza por medio de un aparato denominado luxómetro, que consiste en una celda fotoeléctrica que, al incidir la luz sobre una superficie, genera una débil corriente eléctrica que varía en función de la luz incidente. Dicha corriente se mide con un miliampérmetro cuya escala está calibrada directamente en lux. La Tabla III muestra distintos valores aproximados de iluminancias.

TABLA III.

Mediodía de verano al aire libre, cielo despejado ...	100 000 Lux
Mediodía de verano al aire libre, cielo cubierto	20 000 lux
Lugar de trabajo bien iluminado, recinto interior	1 000 lux
Buen Alumbrado Público	20-40 lux
Noche de Luna Llena	0.25 lux
Noche de Luna nueva (Luz de estrellas)	0.01 lux

IV.8.- LUMINANCIA.

La luminancia de una superficie en una dirección determinada es la relación entre la luminoso de 440 lúmenes, durante su vida promedio de 1000 horas emitirá una cantidad de luz de 440,000 lmh. De este valor habrá que descontar la pérdida de flujo que se produce en el transcurso de su vida, ya que este valor no es constante.

IV.4.- INTENSIDAD LUMINOSA.

Este parámetro se entiende únicamente referido a una determinada dirección y contenido en un ángulo sólido w (Omega Minúscula). Al igual que una magnitud de superficie corresponde un ángulo plano que se mide en radianes, a una magnitud de volumen le corresponde un ángulo sólido o estéreo que se mide en estéreorradianes.

El radián se define como el ángulo plano que corresponde a un arco de circunferencia de longitud igual al radio. El estereorradián se define entonces como el ángulo sólido que corresponde a un casquete esférico cuya superficie es igual al cuadrado del radio de la esfera.

La intensidad luminosa de una fuente de luz en una determinada dirección es igual a la relación entre el flujo luminoso contenido en un ángulo sólido cualquiera cuyo eje coincida con la dirección considerada y el valor de dicho ángulo sólido expresado en estéreorradianes.

La Intensidad Luminosa se representa por la letra I y su unidad es la CANDELA (cd). Su fórmula es:

$$I = \frac{\phi}{w}$$

La candela se define como la intensidad luminosa de una fuente puntual que emite un flujo luminoso de 1 lumen en un ángulo sólido de un estereorradián:

$$cd = \frac{lm}{sr}$$

IV.5.- DISTRIBUCION LUMINOSA. CURVA FOTOMETRICA.

El conjunto de la intensidad luminosa de un manantial en todas direcciones constituye lo que se llama distribución luminosa. Las fuentes de luz utilizadas en la práctica tienen una

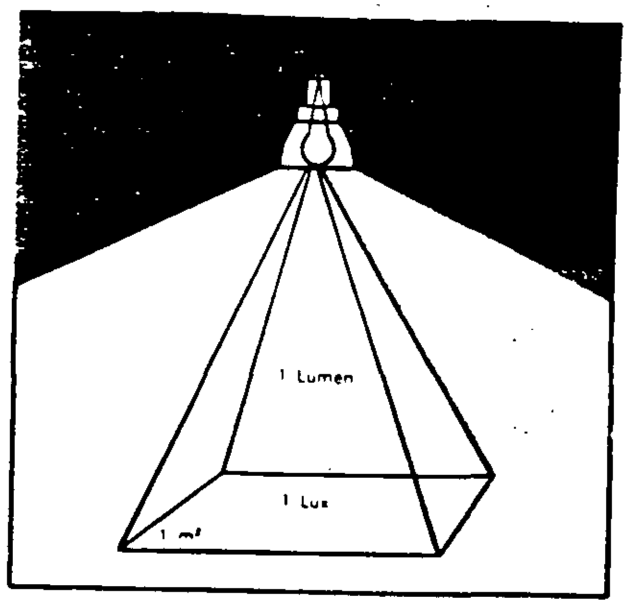


FIG 8.- EL LUX, UNIDAD DE ILUMINANCIA.

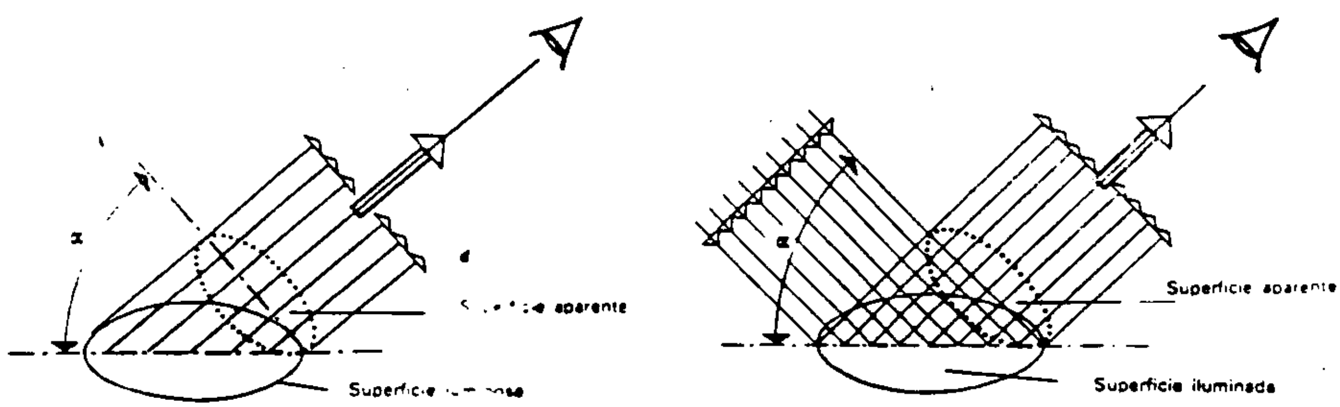


FIG 9 y 10.- TIPOS DE LUMINANCIAS (a) DIRECTA (b) INDIRECTA

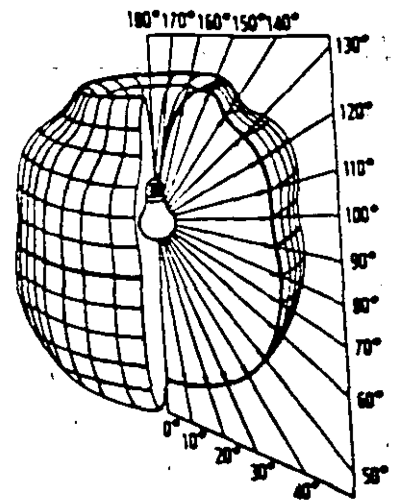
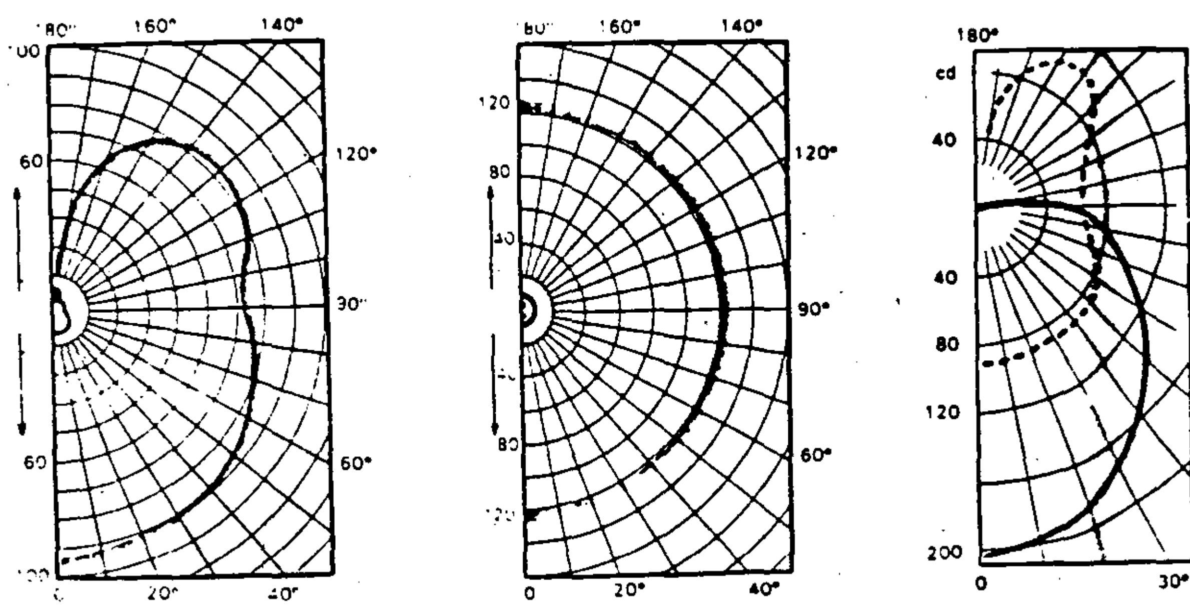


FIG 4.- SOLIDO FOTOMETRICO DE UNA LAMPARA INCANDESCENTE



(5) (6) (7)

FIGS 5, 6, Y 7.- CURVAS FOTOMETRICAS TIPICAS (a) LAMPARA INCANDESCENTE ESTANDAR (B) LAMPARA FLYORESCENTE (C) LAMPARA DE VAPOR DE MERCURIO CON LUMINARIO

TABLA IV.

Sol	150 000	cd/cm
Cielo despejado	0.3-0.5	"
Cielo cubierto	0.03-0.1	"
Luna	0.25	"
Llama de una vela de cera	0.70	"
Lámpara Incandescente Clara	100-200	"
Lámpara Incandescente Mate	5-50	"
Lámpara Incandescente Opal	1-5	"
Lámpara Fluorescente L 40 W/20	0.75	"
Lámpara de Mercurio a Alta Presión 400 W ..	11	"
Lámpara de Aditivos Metálicos 400 W	700	"
Lámpara de Sodio a Alta Presión 400 W	500	"
Lámpara de Sodio a baja Presión 180 W	10	"
Papel Blanco con Iluminación de 1000 lux ..	250	cd/m
Calzada de una calle bien iluminada	2	"

SISTEMAS DE UNIDADES.

El sistema inglés de unidades tiende a desaparecer, por lo que en un futuro próximo todos los países utilizarán el Sistema Métrico, más propiamente llamado el Sistema Internacional de Unidades, abreviado SI. Las principales razones para adoptar el SI son las siguientes: 1) Su extenso uso en la mayor parte de los países del mundo, 2) Son las unidades primarias en el campo científico, y 3) La necesidad de uniformizar los campos de Ciencia e Ingeniería.

En la Ingeniería de Iluminación sólo aquellos términos que involucran unidades de longitud o área se ven afectados por la conversión. Las unidades de lúmenes, candelas, estéreorradianes y eficacia permanecen igual. Por lo tanto sólo las unidades de Luminancia e Iluminancia se ven afectados por esta conversión:

En el sistema Inglés la unidad de Iluminancia es el footcandle (fc) y equivale a un lumen por pie cuadrado, o sea:

$$fc = \frac{lm}{pie^2}$$

La conversión entre Footcandles y Lux se reduce a una simple conversión de pies cuadrados a metros cuadrados porque los lúmenes son comunes:

intensidad luminosa en dicha dirección y la superficie aparente (superficie vista por el observador situado en la misma dirección).

La luminancia se representa por la letra L y su unidad es el NIT (nt) o candela por metro cuadrado (cd/m^2); tiene un submúltiplo que es el STILB (sb) que es candela por centímetro cuadrado (cd/cm^2), empleado para fuentes con elevadas luminancias.

La ecuación que expresa la Luminancia es:

$$L = \frac{I}{S \cos \alpha}$$

donde: $S \cos \alpha$ es la Superficie Aparente

La Luminancia es máxima cuando el ojo se encuentra en la perpendicular a la superficie luminosa, ya que entonces el ángulo es igual a cero y el coseno de α igual a uno, correspondiendo la superficie aparente a la real.

La luminancia puede ser directa o indirecta, correspondiendo la primera a los manantiales luminosos y la segunda a los objetos iluminados (Figuras 9 y 10).

La luminancia es lo que produce en el órgano visual la sensación de claridad, pues la luz no se hace visible hasta que es reflejada por los cuerpos. La mayor o menor claridad conque vemos los objetos iluminados, depende de su luminancia. El libro y la mesa de la figura 11 tienen la misma iluminancia, pero se ve con más claridad el libro porque su luminancia es mayor que la de la mesa.

La percepción de la luz es realmente la percepción de diferencias luminancias. Se puede decir, por lo tanto, que el ojo ve diferencias de luminancias y no de iluminación.

En la Tabla IV se dan algunos valores de luminancias.

La medida de la luminancia se realiza por medio de un aparato especial llamado Luminancímetro o Nitómetro, de construcción similar al luxómetro, del que igualmente existen diversos modelos.

La fuente puntual de una candela producirá un lumen en la unidad de ángulo sólido:

$$\phi = I\ w = cd\ .\ sr = lm$$

La iluminación producida en la superficie interior de la esfera será de 1 lm en pie o un footcandle:

$$E = \frac{\phi}{A} = \frac{1\ lm}{1\ ft^2} = 1\ fc$$

El área total de la superficie de una esfera es 4 R . Por lo tanto, el área total de la superficie de la esfera unitaria es 4 o 12.57 ft . Si el flujo luminoso de 1 lm llega a cada pie cuadrado, la fuente puntual uniforme produce un total de 4 lm o 12.57 lm.

Además de las unidades estudiadas hay otras que se usan regularmente. Algunas de éstas son las siguientes:

Cuando la intensidad luminosa está en candelas y el área está en pulgadas cuadradas, la unidas de luminancia es candelas por pulgada cuadrada, por tanto:

$$1\ fl = \frac{lm}{ft^2} \times \frac{1}{\frac{lm}{cd}} = \frac{1}{\pi} \times \frac{cd}{ft^2} = \frac{1}{144} \times \frac{cd}{pul^2}$$

El número de footlamberts es igual a 1/144 veces el número de candelas por pulgada cuadrada, es decir:

$$\frac{1\ fl}{(1/144)(cd\text{-}pul^2)} = \frac{144\ .\ pul^2\ .\ fl}{1\ cd} = 1$$

Haciendo un análisis comparativo entre dos esferas unitarias para cada sistema de unidades, es decir, una con radio de 1 pie y otra con radio de 1 metro se pueden comprobar varias de las relaciones encontradas (Fig. 13).

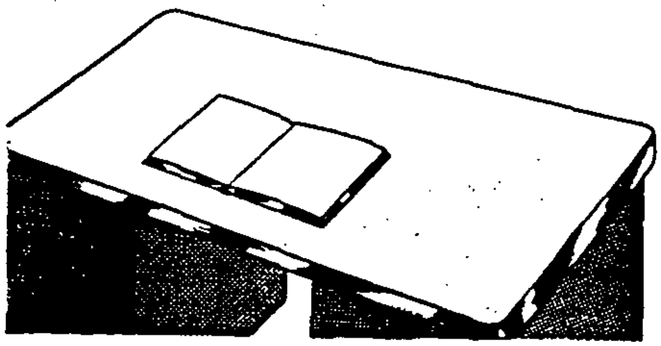


FIG 11.- DIFERENTES LUMINANCIAS DE DOS CUERPOS CON IGUAL ILUMINANCIA

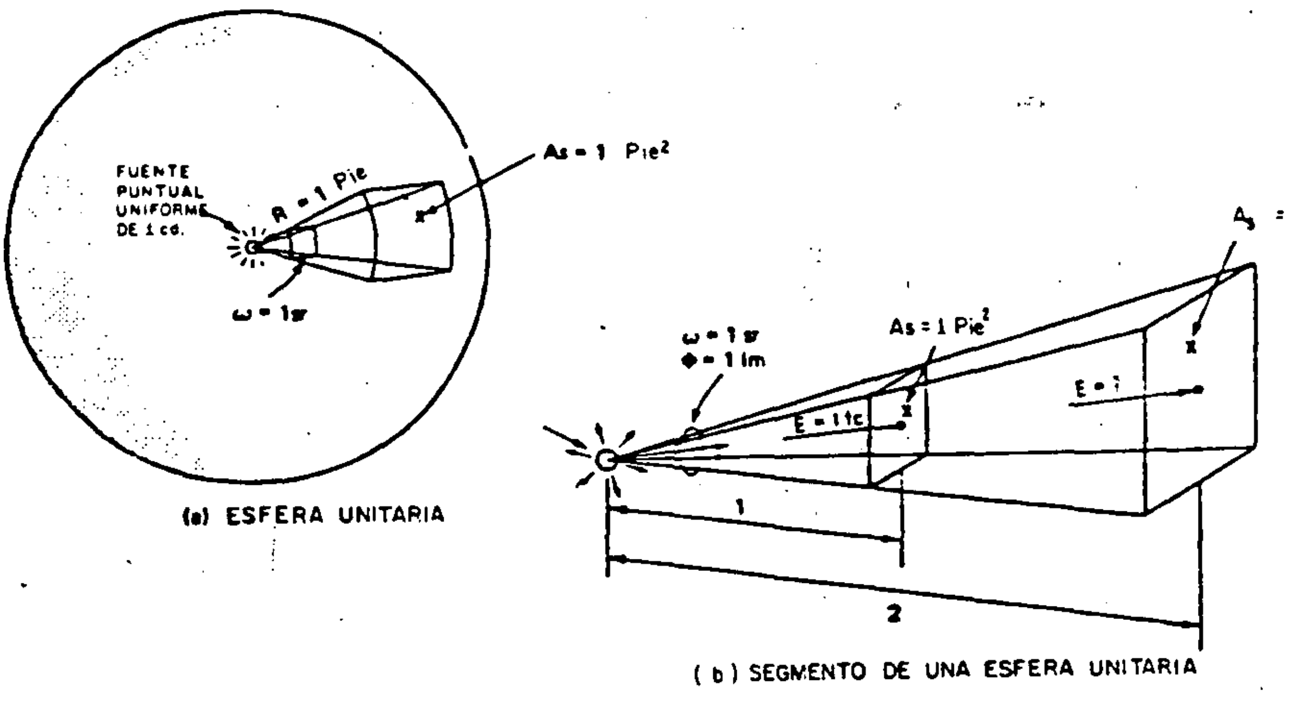


FIG 12.- ESFERA UNITARIA

RESUMEN DE LAS MAGNITUDES Y UNIDADES LUMINOSAS FUNDAMENTALES

MAGNITUD	SIMBOLO	UNIDAD	DEFINICION DE LA UNIDAD	RELACIONES
FLUJO LUMINOSO	ø	Lumen (lm)	Flujo luminoso de la radiacion monocromatica de frecuencia 540 x 10E12 Hz y un flujo de energia radiante de 1/683 watts .	ø = i . w
RENDIMIENTO LUMINOSO		Lumen/watt (lm/w)	Flujo luminoso emitido por unidad de potencia.	= ø/W
CANTIDAD DE LUZ	Q	Lumen por segundo (lms) Lumen por hora (lmh)	Flujo Luminoso emitido por unidad de tiempo.	Q = ø . t
INTENSIDAD LUMINOSA	I	Candela (cd)	Intensidad luminosa de una fuente puntual que emite flujo luminoso de un lumen en un angulo solido de un estereorradian.	I = ø/w
ILUMINANCIA	E	Lux (lx) footcandle (fc)	Flujo luminoso de 1 lumen que recibe una superficie de 1 m .	E = ø/A
LUMIN[illegible]IA	L	Nits (cd/m) Stilb (cd/cm)	Intensidad luminosa de una can-dela por unidad de superficie	L I/A

FACULTAD DE INGENIERIA U.N.A.M.
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T E M A 3

L A M P A R A S.

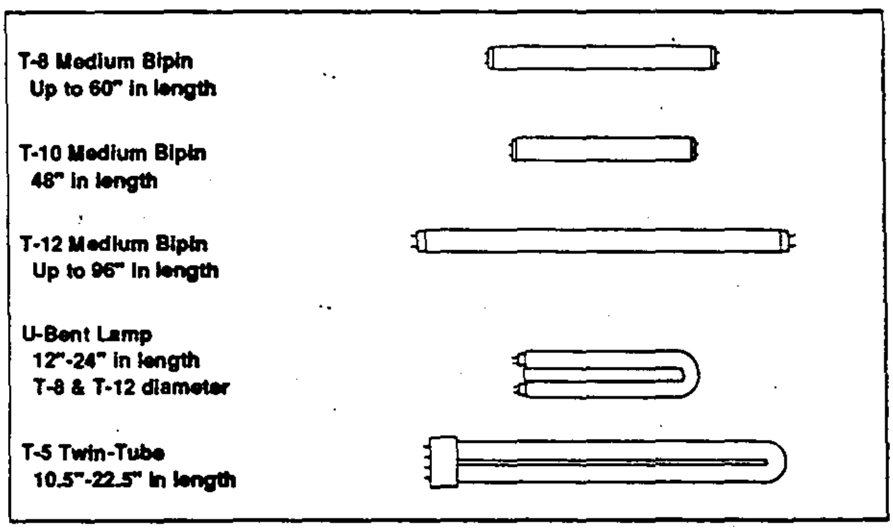
ING. ALFREDO BADILLO.

Full-Size Fluorescent Lamps

California Energy Commission
Building and Appliance Efficiency Office

1993 Advanced Lighting Guidelines March 1993

Figure 1
Full-Size Fluorescent Lamps



Contents

Technology Description

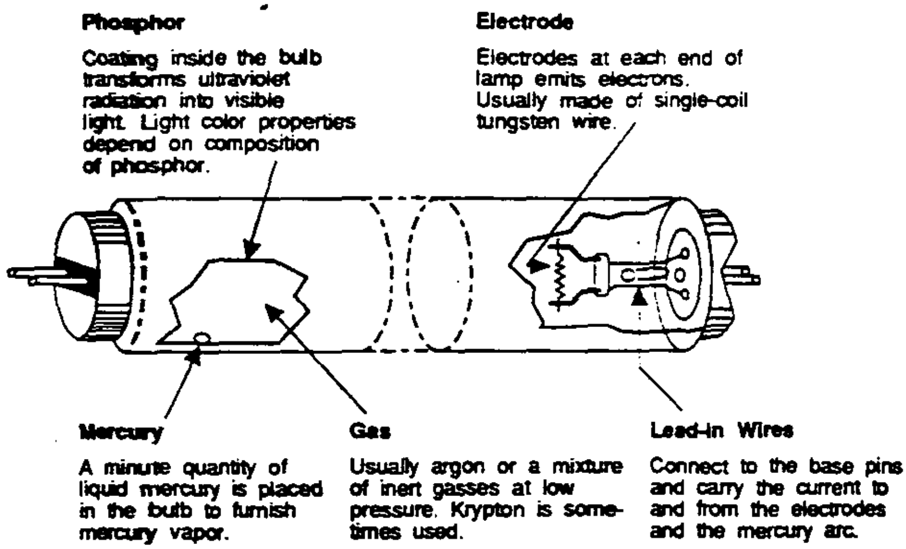
Fluorescent lamp technology has made tremendous advances over the past few years. The trend has been away from high energy consumption lamps to more energy-efficient products, improved color rendition, and a greater selection of color temperatures. These improvements are due in large part to the use of rare earth phosphors in place of the traditional halophosphors used in standard "cool white" lamps. To a lesser degree, efficiency improvements are due to the more widespread use of smaller diameter lamps. The smaller diameter lamps can also increase luminaire efficiency and improve light distribution patterns.

Fluorescent Lamp Operation

A fluorescent lamp is a glass tube with the inside surface coated with phosphor. The tube is filled with argon gas, or sometimes with a mixture of argon and krypton. A small amount of mercury is also inside which is vaporized during lamp operation. Electrodes (also referred to as cathodes) are located at each end of the sealed

Figure 2

Detail of Rapid Start Fluorescent Lamp



tube. When a suitable high voltage is applied across the electrodes, an electric arc discharge is initiated and the resulting current ionizes the vaporized mercury in the tube. The ionized mercury emits ultraviolet (UV) radiation that strikes and excites the phosphor coating on the inside surface of the tube, causing it to glow or *fluoresce* and produce visible light. The exact makeup of the phosphors coating the tube is what determines the color temperature of the light produced by the lamp.

Fluorescent lamps require a ballast to regulate the electric current through the lamp. For optimum performance, a particular ballast must match a specific lamp's current requirements. There are three basic types of fluorescent lamp circuits (see also the guideline on *Energy-Efficient Fluorescent Ballasts*):

- *Preheat Lamps* use an external starter that heats the lamp electrodes before the electric arc is struck. Preheat lamps are relatively uncommon, except in shorter, lower wattage lamps (usually 20 watts or less).
- *Rapid Start Lamps* have ballasts that heat the electrodes prior to lamp starting, as well as during normal operation. This feature helps produce long life in addition to smooth starting. Rapid start lamps start quickly, exhibiting only a brief flicker prior to reaching full light output. These lamps are the only fluorescent lamps suitable for dimming applications.
- *Instant Start ("Slimline") Lamps* have ballasts that do not heat the lamp's electrodes prior to starting or during normal operation. The arc is struck by high voltage discharge only. Instant start lamps are popular for their immediate starting characteristics. Some electronic ballasts operate rapid start lamps in instant start mode, with a reduction in lamp life. Lamp life ratings for instant start lamps generally are lower than for rapid start lamps.

Manufacturers can vary the gas fill, phosphor type and content, as well as the lamp's tube length and diameter, in order to achieve different lamp characteristics. As a result, there is a wide range of lamps being designed and sold. The smallest standard fluorescent lamp is the 6-inch, 4-watt preheat lamp; the largest and most powerful lamps are the eight-foot, 1500 mA, very high output (VHO), rapid start lamps.

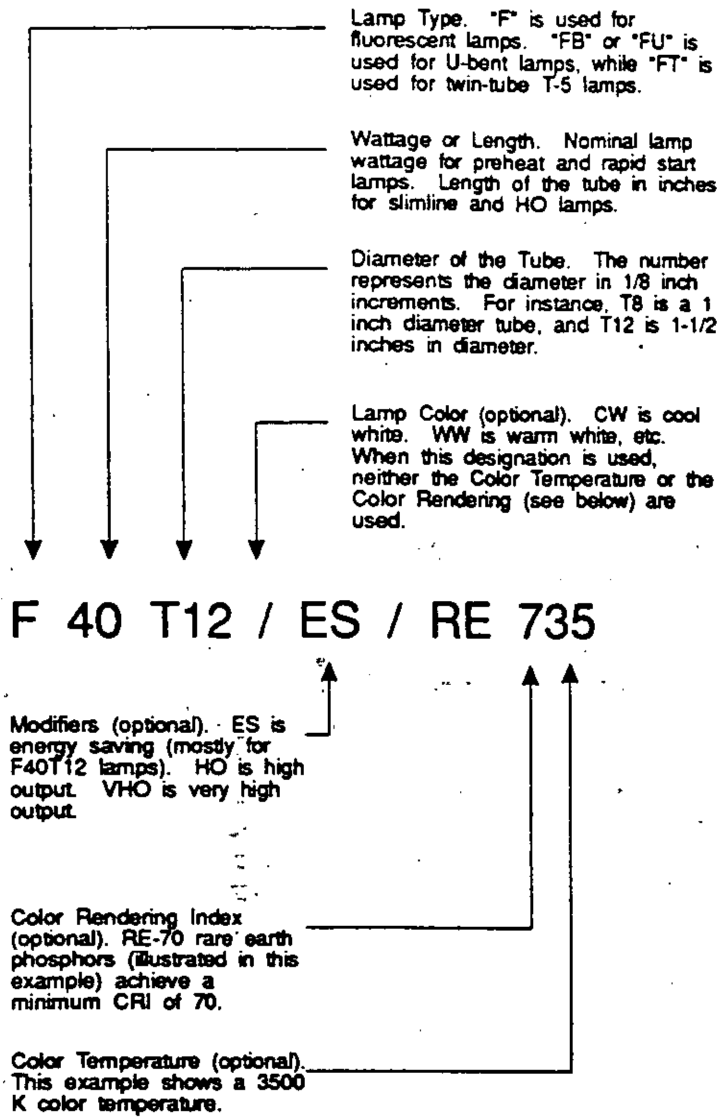
Standard Fluorescent Lamps

The standard 40-watt (F40T12) lamp is filled with argon gas. The most commonly used phosphor is halophosphor "cool white". Standard cool white lamps are rated at 3050 initial lumens. The previous standard lumen rating for cool white lamps, 3150 lumens, was recently reduced by about 3% due to phosphor changes necessitated by federal regulations.

Figure 3 illustrates the nomenclature used to specify fluorescent lamps. The standard 4-foot F40 rapid start fluorescent lamp is the most common light source in commercial facilities. The most common diameter is 1.5 inches (designated a T-12, where the number following the "T" represents the diameter of the tube in 1/8 of an inch increments). There are about ten times more rapid start F40T12 lamps in use than all other types combined. Obviously, any improvement in efficacy for this type of lamp can have profound energy savings implications.

Figure 3

Fluorescent Lamp Nomenclature



High demand for the F40T12 lamp over the years has resulted in mass production and low cost. The most popular fluorescent lamp configuration from the 1950s through the 1970s was 2-F40T12 lamps, producing 3150 lumens each on a single ballast. The system consumed approximately 96 watts, including ballast losses, and usually generated at least 95% of the rated lamp lumens in open air at a temperature of 25 °C (77 °F). This resulted in a light output of approximately 5985 lumens at a "cost" of about 96 watts for an efficacy of approximately 62 lumens per watt.

When connected with conventional ballasts, most lamps deliver less than 100% of their rated lumens. The percentage of actual lumens generated is known as the *ballast factor*, an important figure to consider when making lighting calculations. The ballast factor is the ratio of the light produced by a particular lamp ballast system to the rated light output of the same lamp(s) on an ANSI reference ballast operated in free air at 25 °C (77 °F). The term "ballast factor" implies that it is a property of the ballast, but it is really a property of the lamp-ballast system. The ballast factor for a given ballast will be different, for instance, depending on whether it is operating a F40T12 lamp or a F40T12/ES lamp. See the *Energy-Efficient Fluorescent Ballasts* guideline for more information on the ballast factor.

Standard Fluorescent Lamps and Lighting Legislation

The U.S. Energy Policy Act of 1992 (Public Law 102-486), signed into law on October 24, 1992, contains energy efficiency standards and other regulations that will preclude certain lamps from being manufactured or imported into the U.S. after a transition period. With respect to fluorescent lamps, full-wattage 4-foot T-12 lamps with calcium halophosphors (e.g. cool white and warm white halophosphor lamps) will not longer be permitted. However, reduced-wattage lamps (34-watt F40T12/ES) with the same phosphors will continue to be allowed. Full-wattage 4-foot T-12 lamps with high CRI rare earth phosphors will be permitted. Similar restrictions will apply to 8-foot T-12 lamps. This legislation does not affect T-8 lamps. The transition lasts until April of 1994 for 8-foot lamps and October of 1995 for 4-foot lamps. The Act exempts several categories of lamps.

Energy Saving (ES) Lamps

In response to the energy crises of the 1970s, lamp companies introduced "energy saving" lamps with krypton added to the gas fill. These lamps have the designation "F40T12/ES" in this guideline. These lamps draw less power than standard F40T12 lamps (usually about 34-35 watts). F40T12/ES lamps can be operated by standard F40T12 ballasts, so they may be readily substituted in existing lighting systems. Both wattage and light output are reduced proportionately. However, the slight reduction in light output is generally acceptable to most users, given the energy savings and system efficacy.

ES lamps have a lower ballast factor than standard F40T12 lamps (about 0.87 with a standard energy-efficient ballast, as opposed to about 0.95 for standard F40T12 lamps). The lower ballast factor further reduces light output. The lower lumen output of ES lamps means that their most appropriate application is for lamp retrofit or replacements in overlighted spaces. Substituting F40T12/ES lamps for standard F40T12 lamps reduces input wattage by about 12% to 15%. Lumen output is reduced by 18% to 20% for a two-lamp system.

Energy saving lamps are more sensitive to low temperatures than standard lamps. Minimum starting temperature is about 16 °C [60 °F], as opposed to 10 °C [50 °F]) for standard 40-watt F40 lamps, and they are not recommended for dimming applications. ES lamps are manufactured for many different types of fluorescent lamps, including rare earth phosphor lamps, slimlines, and high output (HO) lamps.

Rare Earth (RE) Phosphor Lamps

Rare Earth (RE) phosphor technology improves the performance of fluorescent lamps. RE phosphor compounds are selected for their ability to produce visible light at the most sensitive wavelengths of the eye's red, blue and green sensors. When compared with conventional halophosphors, such as cool white (with a CRI of 60-62), RE phosphors produce better color rendering and higher efficacy, while improving lumen maintenance characteristics. For reasons of lumen maintenance, rare earth materials are required in small diameter lamps, such as compact fluorescents.

RE phosphors raise lumen output up to 8% over conventional halophosphors. RE phosphor lamps are available for most fluorescent lamp configurations and are available in a wide range of color temperatures. Two generic types of RE phosphor lamps are offered: RE-70 and RE-80.

RE-70 Lamps

The expression "RE-70" refers to a fluorescent lamp containing phosphor mixes that create a CRI of 70 to 79. These lamps, formerly called "thin coat triphosphor" lamps, contain less of the rare earth phosphors than do the coatings of more expensive, high-CRI RE-80 lamps. They increase lumen output of 4-foot lamps by 5% to 6%.

RE-80 Lamps

RE-80 fluorescent lamps, sometimes referred to as "thick-coat triphosphor" or "high CRI" lamps, increase lumen output up to 8% over halophosphor cool white, and increase CRI to 80-89. The additional rare earth phosphor content in the coating of these lamps improves color rendering but also increases lamp cost.

Figure 4 lists the availability of RE phosphor lamps in terms of color temperatures and CRIs. In addition, see Figure 8 for some performance characteristics of RE lamp types as compared to halophosphor cool white lamps.

Heater Cutout Lamps

In a rapid start lamp, it is possible to disconnect the lamp electrode heater after the lamp has started. This is accomplished with a thermal switch in the lamp. This reduces lamp power by about 2.0 to 2.5 watts per lamp with no reduction of light output. These lamps are known as "cathode cutout," "heater cutout," or "ES+" lamps. They are suitable for retrofit applications, but are not recommended for use with electronic ballasts or in dimming applications.

Disconnection of a lamp's electrode heaters can also be achieved with heater cutout ballasts, used with conventional rapid start lamps. These ballasts are not recommended for use in conjunction with heater cutout lamps. For more information, see the discussion on heater cutout ballasts in the *Energy-Efficient Fluorescent Ballasts* guideline.

A drawback of ES+ lamps is that there is a restrike time of one to two minutes if the lamp is extinguished and then immediately restarted. Because of this, use of ES+ lamps is not recommended with occupant sensors or other frequent

Figure 4
Availability of RE Lamp Products

CCT (K)	CRI Range	Generic Designation	Various Manufacturer Designations*	Color Temperature Matches
3000	70-79	RE-730	D30 SP30 Spec30 TC730	Incandescent Tungsten Halogen
	80-89	RE-830	D830 30K SPX30 30U AX30 TC830	3000 K Metal Halide White Sodium
3100	70-79	RE-731	31K	Same As Above
3500	70-79	RE-735	D35 35K SP35 Spec35 TC735	Tungsten-Halogen 3300-3700 K Metal Halide
	80-89	RE-835	D835 35K SPX35 35U AX35 TC835	White Sodium
4100	70-79	RE-741	D41 41K SP41 Spec 41 TC741	Standard Metal Halide
	80-89	RE-841	D841 41K SPX41 41U AX41 TC841	
5000	80-89	RE-850	F0U AX50	Daylight

*Note: These are some designations of selected major manufacturers. To be assured of the proper color temperature and CRI, check each manufacturer's data to determine the exact color designation.

switching applications. Some manufacturers, but not all, have derated the lamp life by 25% for heater cutout lamps. In most applications, however, reduced lamp life will be more than offset by potential energy savings.

Extended Output (EO) Lamps

EO lamps are premium versions of standard 40-watt F40T12 lamps which, due to gas fill, redesigned electrodes, thicker or more efficient phosphors, and/or tube diameter, generate more light than standard cool white F40T12 lamps. In some cases, this is accomplished with a slight increase in lamp wattage. Compared to standard F40T12 lamps, they offer higher efficacy, increase both lumen output (up to 21%), and lamp life (20%), and improve lumen maintenance, and color rendering. The "EO" nomenclature is not used by any manufacturer; current products use manufacturer-specific trade names or designations.

EO lamps were originally intended to replace F40T12 lamps in applications requiring increased light, or in situations where retrofits or delamping reduced light levels too much. EO lamps can be used in the same luminaires as standard 40-watt F40T12 lamps, without a change of sockets or ballasts. This makes EO lamps especially useful in retrofit applications requiring an increase in light output, as no replacement of luminaire hardware is required. More currently, EO lamps are receiving increased consideration in new construction applications.

EO lamps may be operated with either electronic or magnetic ballasts. EO lamps are only available for 40-watt F40 lamps, in both T-12 and T-10 diameters, as described below.

T-12 EO Lamps

F40T12/EO lamps typically deliver about 11% to 15% more light output in some designs than standard halophosphor lamps. Light output is rated at 3400 lumens for the RE-70 lamp and 3500 lumens for the RE-80 version. Color temperatures of 3000 K, 3500 K, and 4100 K are available. Rated lamp life is 24,000 hours at 3 hours per start.

T-10 EO Lamps

F40T10/EO lamps can produce significantly more light output than standard F40T12 halophosphor lamps. Rated initial lamp lumen output for premium T-10 lamps is 3700 lumens, made possible by increased power and RE-80 phosphor coatings. The only available T-10 lamp size at this time is the 4-foot replacement for the standard F40T12. It actually consumes about 42 watts, but due to its higher voltage, it draws slightly less current (about 400 mA), and ballast losses are lower. A typical energy-efficient magnetic ballast for two F40T10 lamps will draw about 92 watts, with a ballast factor of 0.95, and a system efficacy of about 76 lumens/watt. Some T-10 lamps are sensitive to variations in voltage input and may not start properly with the 40-watt T-12 ballast over the entire voltage input range. One manufacturer makes a ballast to match the T-10 lamp. T-10 lamps also have a rated lamp life of 24,000 hours. At present, T-10 lamps are premium-priced products.

U-Tube Lamps

Another popular version of the standard 40-watt F40T12 fluorescent lamp is a U-shaped configuration, usually referred to as a "U-tube" or "U-bent lamp". These lamps are designated "FB" by some manufacturers, while others use a "/U designation. They are available with both 6-inch and 3-5/8-inch leg spacing, and have an overall length of about 22 inches. Some products are manufactured with rare earth phosphors. U-tubes are also available in 34-watt ES versions and with RE phosphors.

U-lamps are used mostly with square luminaires, such as 2' x 2' troffers or surface mounted luminaires. The halophosphor cool white version of the lamp produces about 2800 lumens; RE-80 phosphors raise the lumen rating to approximately 3000. U-lamps are rated for an effective life of up to 18,000 hours at 3 hours per start.

Slimline Lamps

Slimline fluorescent lamps are recognizable by their single pin bases. While slimlines are available in T-6, T-8 and T-12 diameters and in lengths ranging from 24 to 96 inches, the focus of this document is on the 425-mA F96T12 configuration, popular in many commercial applications.

Slimline lamps use a lamp designation code different from most other fluorescent lamps: the number following the "F" designates the lamp length in inches, not the wattage. For example, "F96T12" refers to a slimline lamp 96 inches long and 1.5 inches in diameter. Lamp wattage must be determined from lamp catalogs. The F96T12 lamp, for instance, is actually 75 watts.

Slimline lamps are popular in many commercial applications using open luminaires. Eight-foot slimline lamps are more efficacious than standard F40T12 rapid start lamps, due to instant start operation. In addition, the greater length of the F96T12 creates a higher lumen package, due to reduced lamp end losses as a percentage of the total lamp wattage (end losses are constant, so increasing the length of the tube reduces their impact.)

Slimline lamps are available in standard, 60-watt ES, and versions. Instant start operation means that the rated lamp life of slimline lamps is significantly shorter than in rapid start lamps. The F96T12 slimline lamp, for instance, is rated at 12,000 hours, at 3 hours per start. It is also worth noting that magnetic ballasts for slimline lamps have a lower (i.e. noisier) sound rating than standard magnetic ballasts

High Output (HO) Lamps

Rapid start fluorescent lamps that operate at 800 mA are known as high output (HO) lamps. They have a recessed double contact base and require a special ballast. HO lamps use the same designation terminology as slimline lamps. Thus, an 8-foot HO lamp uses the designation "F96T12/HO". HO lamps are available in lengths ranging from 18 inches to 96 inches. The 110-watt F96T12 and 85-watt F72T12 are the most popular configurations and are commonly used in many commercial and industrial applications. HO lamps are available with rare earth phosphors and in reduced wattage, ES versions.

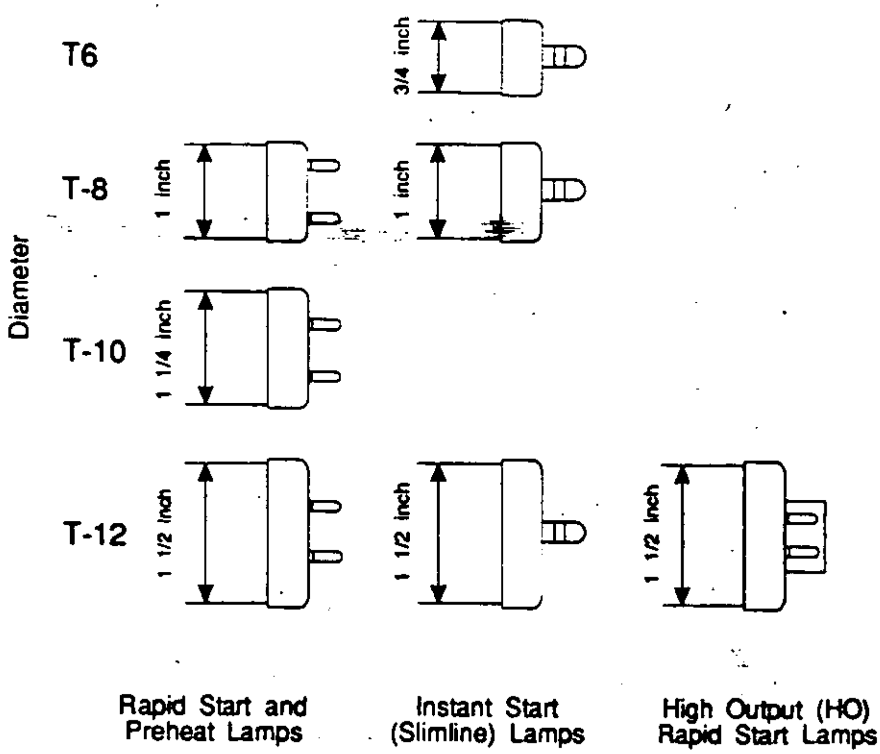
A standard 8-foot HO lamp has a rated lamp output of 8900 lumens, and a lamp life rating of 12,000 hours (3 hrs/start operation). RE-70 and RE-80 phosphor coatings raise the light output to 9200 and 9350 lumens, respectively. HO lamps increase lumen output significantly by drawing considerably more power than standard fluorescent lamps. For example, a cool white 4-foot HO lamp (F48T12/HO) produces about 4300 lumens and draws about 60 watts, not including ballast losses. A standard F40T12CW lamp, by comparison, produces 3050 lumens and uses 40 watts.

Very High Output (VHO) Lamps

The most powerful fluorescent lamp is a 1500 mA lamp, known as a very high output (VHO) lamp. An F96T12/VHO lamp uses conventional halophosphors and produces 13,500-15,700 initial lumens, while consuming 215 watts, not including ballast losses. Some reduced wattage, ES versions of VHO lamps are available.

Generally, HO and VHO lamps are not a practical retrofit situation for standard fluorescent lamps due to their different base configurations (recessed double contact). However, there are many cases in new construction where the installation of F96T12/HO lamps over standard F40 lamps should be considered. For example, including ballast factors, a single F96T12/HO lamp produces about 47% more lumens than two standard F40 lamps, while using approximately 33% more power. This translates to a 10% to 11% increase in efficacy. In general, HO lamps should be considered in applications where light output is of paramount importance, and where a shorter lamp life (12,000 hours) and increased ballast noise is acceptable.

Figure 5
Standard Fluorescent Lamp Bases



Advanced Products

In addition to the EO family of lamps, two other fluorescent lamp types have significantly improved efficacy when compared with the standard F40T12 lamp-ballast system. These are the T-8 and T-5 lamp families. T-8 lamps use the common medium bipin base, while T-5 twin-tube lamps are configured with a four-pin 2G11-type base. Smaller lamp diameters and the exclusive use of rare earth phosphors increase the efficacy of these lamps over standard F40T12 lamps. In addition, specially designed ballasts may be used for even greater increases in lamp-ballast system efficacy. Data regarding these lamp types is summarized in Figure 6.

T-8 Lamps

The 265 mA T-8 fluorescent lamp-ballast system is a relatively recent energy-efficient lighting product. Introduced to the American market in 1982, these lamps are now made by all major U.S. lamp manufacturers. The straight T-8 lamps have the same medium bipin bases as T-12 lamps, allowing them to fit the same sockets (this is not true for the U-bent T-8 lamps, which have different leg spacings than their T-12 counterparts). However, T-8 lamps have different electrical characteristics, so they may not use a standard F40T12 type lamp ballast designed for 430 milliampere operation. The standard T-8 lamp family is

Figure 6

Advanced Fluorescent Lamp Technologies Data

Lamp Style	Watts	Initial Lamp Lumens	Normal Length
Straight T8 Bipin Lamps			
F17T8	17	1350	2'
F25T8	25	2150	3'
F32T8	32	2900	4'
F40T8	40	3650	5'
U-Shaped T8 Bipin Lamps			
FB16T8	16	1250	1'
FB24T8	24	2050	1.5'
FB31T8	31	2800	2'
Straight F40/EO Bipin Lamps			
F40T12/EO/RE70	40	3400	4'
F40T12/EO/RE80	40	3500	4'
F40T10/RE80	42	3700	4'
T-5 Twin-Tube Lamps			
FT18W/2G11	18	1250	10.5"
FT27W/2G11	27	1800	12.85"
FT39W/2G11	39	2850	16.5"
FT40W/2G11	40	3150	22.5"
FT50W/2G11	50	4000	22.5"
FT55W/2G11	55	4800	21.0"

designed for 265 mA operation, but T-8 lamps are also being designed to operate with special ballasts at substantially higher power levels. There is only a minor cost difference between a standard T-8 lamp-ballast system and a standard F40T12 lamp-ballast configuration.

T-8 lamps are available in several straight tube and U-bent configurations. Generally, they are available in color temperatures of 3000 K, 3500 K and 4100 K. Depending on the manufacturer they have either RE-70 or RE-80 phosphor coatings. Rated power ranges from 16 to 40 watts.

Like standard F40T12 lamps, T-8 lamps are rated at 20,000 hours for 60 Hz rapid start operation. However, for highest efficacy, they are often matched with an electronic ballast that operates the lamps in an instant start mode and at [illegible] KHz (electronic ballasts for rapid start operation are also available). Instant start operation of T-8 lamps reduces rated lamp life by [illegible]% (based on 3 hours per start operation), but lamp efficacy is increased by more than 10% when compared with magnetically-ballasted operation. In most commercial applications, where lamps are on for a period of 10 hours between starts, lamp life is only slightly less than that of rapid start operation. Like T-12 lamps, T-8 lamps may be dimmed, but they require specialized dimmers and ballasts to work properly.

T-8 lamps offer several advantages over standard (non-RE phosphor) T-12 lamps:

- The two lamp F32T8 system with an energy-efficient magnetic ballast has an efficacy of 78 lumens/watt, as compared to 68 lumens/watt for a standard two-lamp F40 T12/RE70 lamp system.
- The two-lamp F32T8 system with an instant start electronic ballast can achieve an efficacy of up to 90 lumens per watt. Given optimum electronic ballast designs, a representative efficacy for an electronically ballasted two-lamp F40T12/RE70 system is about 78 lumens/watt.
- All T-8 lamps contain rare earth phosphors. RE phosphor coatings give T-8 lamps improved color rendering and lamp lumen maintenance over T-12 halophosphor lamps.
- T-8 lamps purchased in large quantities are not much more expensive than halophosphor T-12 lamps, and are actually less expensive than either 34-watt or 40-watt T-12 lamps with RE phosphors. Additionally the cost of T-8 lamp system installations is often subsidized by utilities in the form of rebates or incentives. Overall, on a life-cycle cost basis, a T-8 lamp-ballast system is usually a better investment than any 4-foot T-12 system.

All manufacturers now make T-8 lamps. As Figure 6 shows, T-8 lamps are currently offered in standard 2, 3, 4, and 5-foot straight lamps, as well as in 1, 1.5, and 2-foot- U-shaped lamps. In addition, an 8-foot T-8 lamp has been announced in a single-pin slimline-type configuration.

T-5 Twin-Tube Fluorescent Lamps

T-5 twin-tube fluorescent lamps range in length from 10.5 inches to 22.5 inches. As such they are particularly effective in applications calling for smaller, more compact luminaires. Lamps of up to 55 watts are available, allowing for nearly any general/ambient lighting application. T-5 twin tube lamps now bear a designation code prefixed by the letters "FT."

Despite their small sizes, T-5 lamps have high lumen output, excellent color rendering, and good efficacy, due to the use of RE phosphor coatings. T-5 lamps use RE-80 high color rendition phosphors and are available in color temperatures of 3000, 3500 and 4100 K. T-5 twin-tube lamps operate at currents ranging from 250 to 550 mA and are configured with four-pin 2G11-type bases. In general, they require dedicated ballasts; however, the 270 mA FT40T5 twin-tube lamp may be used with a standard T-8 rapid start ballast.

T-5 twin-tube lamp configurations discussed here are available in 18, 27, 39, 40, 50, and 55 watts. The manufacturer of the 55-watt version claims that the lamp produces 4800 lumens and has a life of 20,000 hours when operated on an electronic ballast. The performance characteristics of these products vary greatly from lamp to lamp, as shown in Figure 7.

Performance data for full-size fluorescent lamp-ballast systems (two-lamp systems) may be found in Figure 8.

Application Guidelines

Advanced technologies in full-size fluorescent lamps are used to make rapid start straight and U-shaped lamps with unit lumen output comparable to the standard 40-watt F40T12 lamp. The technologies may be considered in all applications where F40T12 lamps are suitable.

T-12 Lamps

Retrofits: Consider the use of heater cutout lamps in applications where a 1-2 minute restrike time can be accepted. Any of the advanced technology T-12 lamps can be used as energy-efficient retrofits for standard F40T12 lamps.

New Construction: Consider the use of rare earth phosphor (RE) and high output (HO) lamps when their extra lumen output allows for design with fewer luminaires or fewer lamps per luminaire.

Extended Output T-10 and T-12 Lamps

Retrofits: Good applications for EO lamps are existing situations where delamping (alone, or combined with other retrofits, such as specular imaging reflectors) may produce unacceptably low lighting levels. EO lamps are designed specifically for these situations.

New Construction: Although EO lamps were initially introduced as retrofits for standard T-12 lamps, they can be considered for new construction applications where higher lighting levels are required. For example, occasional lighting problems may result from using standard luminaires and T-12 lamps. Without changing the lighting design, a 13% increase in lighting level, with only a 5% increase in power, can be obtained by using T-10 lamps and appropriate luminaires. In addition, there may be applications when fewer luminaires are required to achieve a design illuminance level, if T-10 lamps are used instead of T-12s.

Figure 7

T-5 Twin-Tube Rapid Start/Preheat Lamps w/2G11 Bases

Lamp Type	Ballast Type	Input Watts	Typical Ballast Factor	Lumen Output	System Efficacy (L/W)
FT18W/2G11 1250 Lumens	370mA Magnetic PH	22	.90	1125	51
FT18W/2G11 1250 Lumens	270mA Magnetic RS	23	.90	1125	49
	265mA Electronic IS	17	.95	1199	70
FT24W/2G11 1800 Lumens	340mA Magnetic RS	32	.925	1665	52
	265mA Electronic IS	21	.810	1458	69
FT39W/2G11 2900 Lumens	430mA RS	51	.925	2682	53
	265mA Electronic IS	26	.690	2001	77
FT40W/2G11 3150 Lumens	265mA Magnetic RS	43	.930	2930	68
	265mA Electronic RS	36	.830	2615	73
FT50W/2G11 4000 Lumens	430mA Electronic IS	54	.97	3880	72
FT55W/2G11 4800 Lumens	550mA Electronic IS	62	0.97	4656	75

Notes:
Lamp life will vary, depending on lamp current and ballast starting mode.

Figure 8

Lamp-Ballast System Comparison: Two-Lamp Open Air Systems

		Lamp-Ballast System				Comparison		
Lamps	**Ballasts**	**Test Ballast Factor**	**Lumen Output**	**Input Watts**	**Efficacy L/W**	**Input Watts**	**Lumen Output**	**System Efficacy**
40W F40T12 4100K CW 3050 Lumens	Magnetic EE	.94	5734	88	65	Base 100%	Base 100%	Base 100%
40W F40T12 4100K RE-70 3200 Lumens	Magnetic EE Heater Cutout Electronic RS	.94 .85/.95 .88	6016 5312/6080 5632	88 69/80 72	68 77/76 78	100% 78%/91% 82%	105% 93%/106% 98%	105% 118%/117% 120%
40W F40T12 4100K RE-80 3300 Lumens	Magnetic EE Heater Cutout Electronic RS	.94 .83/.95 .88	6204 5478/6270 5808	88 69/80 72	71 79/78 81	100% 78%/91% 82%	108% 96%/109% 101%	109% 122%/120% 125%
34W F40T12/ES 4100K RE-70 2800 Lumens	Magnetic EE Heater Cutout Electronic RS	.87 .81/.88 .88	4872 4536/4928 4928	72 58/66 62	68 78/75 79	82% 66%/75% 70%	85% 79%/86% 86%	105% 120%/115% 122%
34W F40T12/ES 4100K RE-80 2850 Lumens	Magnetic EE Heater Cutout Electronic RS	.87 .81/.88 .88	4959 4617/5016 5016	72 58/66 62	69 80/76 81	82% 66%/75% 70%	86% 81%/87% 87%	106% 123%/117% 125%
32W F40T12/ES– 4100K RE-70 2650 Lumens	Magnetic EE	.87	4611	67	69	76%	80%	106%
42W F40T10 4100K RE-80 3700 Lumens	Magnetic EE Heater Cutout Electronic	.95 .85/.95 .85	7030 6290/7030 6290	92 74/84 74	76 85/84 85	105% 84%/95% 85%	123% 110%/123% 110%	117% 131%/129% 131%
32W F32T8 4100K RE-70 2900 Lumens	Magnetic EE Electronic RS Electronic IS	.94 .88 .95	5452 5104 5510	70 62 63	78 82 87	82% 70% 72%	95% 89% 96%	120% 127% 135%
32W F32T8 4100K RE-80 3050 Lumens	Magnetic EE Electronic RS Electronic IS	.94 .88 .95	5734 5368 5795	70 62 63	82 87 92	82% 70% 72%	100% 94% 101%	126% 133% 142%
FT40W/2G11T5 4100K RE-80 3150 Lumens	Magnetic Electronic RS	.93 .83	5859 5229	86 71	61 74	109% 81%	102% 91%	94% 114%
FT50W/2G11 T5 4100K RE80 4000 Lumens	Electronic RS	.97	7760	106	73	120%	135%	112%
FT55W/2G11 T5 4100K RE80 4800 Lumens	Electronic IS	.93	8928	110	81	125%	156%	125%
75W F96T12/IS 4100K Slimline Halophosphor 6150 Lumens	Magnetic EE Electronic IS	.94 .86	11,560 10,580	158 130	73 81	90% 74%*	101% 922%	112% 125%
110W F96T12/HO 4100K Halophosphor 8900 Lumens	Magnetic EE Electronic RS	.94 .81	6,732 14,418	237 290	71 76	135% 108%	146% 134%	109% 126%

Notes:

Open air bare lamp tests as per ANSI C82.2.
Ballasts cited are specific commercial ballasts available on the current market; use of other ballasts will produce different results.
Figures given for heater cutoff ballasts represent values for both reduced and full light output models.

T-8 Lamps

Retrofits: In retrofit situations involving F40T12 lamps, where the existing ballast must be changed, T-8 lamp-ballast system retrofits are often very cost effective, especially when utility rebates are factored in. However, if the existing ballast is an energy-efficient F40T12 type, in good condition, then an energy-efficient T-12 or T-10 system retrofit is usually more cost-beneficial in the short term.

New Construction: T-8 lamps are excellent for all new installations including:

- Offices
- Retail stores
- Commercial and industrial lighting
- Special applications, such as task lights, under cabinet lights, cove lights, and surface and decorative lights

Based on efficacy alone, T-8 lamps are generally superior to any T-12 technology. Considering the fact that T-8 lamps make many popular luminaires more efficient, a T-8 system with magnetic ballasts will typically provide 8% to 9% more light at 4% to 9% fewer watts than a system using F40T12/ES lamps with equivalent color rendering capabilities. Efficacy is further increased with the use of electronic ballasts. The lamp cost for larger commercial projects in major metropolitan areas is about the same as for T-12 lamps.

T-5 Lamps

Applications for T-5 twin-tube lamps are generally limited to new construction, as they require special sockets and ballasts. At present several luminaire designs are being developed to take advantage of this relatively new lamp technology.

T-5 lamps are ideal for applications requiring relatively high lighting levels from compact luminaires. 1' X 1' recessed parabolic troffers utilizing T-5 lamps provide good light levels while fitting in one-quarter the ceiling space of a conventional 2' X 2' troffer. The use of 1'x 1' troffers in lieu of other types of downlights allows for the use of effective, efficacious sources and electronic ballasts in compact recessed luminaires. Similarly, 2' x 2' and other types of general lighting luminaires are appropriate in a variety of applications with energy saving results. For example, 40-watt U-lamps, the traditional lamps for 2' x 2' troffers, can be replaced by a smaller (22.5 inch) and more efficient (3200 lumens to 2800 lumens) FT40T5 compact fluorescent alternative, with no major drawbacks. Similarly, the high-powered FT50 and FT55 configurations perform well in well-shielded 2' X 2' troffers, as well as in specially designed chandeliers, pendants, wall washers, and indirect systems.

Overall, the applications for T-5 twin-tube lamps should increase as luminaire manufacturers begin to take advantage of this technology to build luminaires that are functional, energy-efficient and attractive. For example, for maximum lighting level applications, the new 55-watt T-5 lamp promises to provide the most light output of any of the newer technology lamp products. This may allow for designs with fewer luminaires and/or fewer lamps per luminaire, reducing overall costs with little loss of light levels. However, with a light output of 4800 lumens per lamp, luminaires with good shielding characteristics will be required to prevent glare.

Figure 9

Lamp-Ballast Characteristics in 2' X 4' Troffers

Lamp Type	Ballast Type	Initial Footcandles Small Room (RCR =5)	Initial Footcandles Large Room (RCR=1)	Power Density (Watts/ Ft²)	Comparative Power Density
F40T12	Magnetic	50	68	1.23	100%
F40T12	Electronic RS	47	64	1.10	89%
F40T12/ES	Magnetic	41	56	1.09	89%
F40T12/ES	Electronic RS	41	55	0.90	73%
F40T12/ES+	Magnetic	38	52	0.87	71%
F40T10	Magnetic	57	78	1.29	105%
F40T10	Electronic RS	54	74	1.19	97%
F32T8	Magnetic	46	63	1.01	82%
F32T8	Electronic IS	47	63	0.90	73%

Notes:
1. Footcandle figures calculated using Lumen Method. *See Computer Aided Lighting Design* guideline for discussion of the benefits of Point-by-Point calculations.
2. All calculations are for initial footcandles and include ballast and thermal factors as found in or extrapolated from Figure 3-17 in *Luminaires and Lighting Systems* guideline.
3. All lamps, except T-10s are RE-70 phosphor coated; T-10s are RE-80.
Consult IES recommended lighting levels for specific activities.

Examples

New General Lighting Systems

A typical general lighting system using standard 3-inch deep cell, semi-specular, recessed parabolics utilizes recessed three-lamp troffers on 8' by 10' centers. Figure 9 illustrates some typical results that can be obtained by different lamp-ballast combinations in non-air handling, high efficiency parabolic troffers in a room with white tile ceiling, light colored walls and normal carpet color. All footcandle levels are initial.

A Retrofit Situation

A traditional lens-troffer design from the early 1970's utilizes four-lamp troffers on 8' by 8' centers. [illegible]ulting system generates [illegible] maintained footcandles [illegible] at 2.7 watts/ft^2 using [illegible]mps, and about 84 [illegible]es at 2.4 watts/ft^2 using [illegible]2/ES lamps.

A survey of many office spaces in particular would reveal that lighting levels are excessive for some situations. Average illuminance levels between 20 and 50 footcandles (IES illuminance category "D") are usually appropriate for most visual tasks of medium contrast or small size. Higher task illuminance levels are needed only for the most demanding of visual tasks. As such, excellent energy-saving opportunities exist. In these cases, the lighting professional should examine several options:

- Check the ballast. If it is not an "energy-efficient" type, it almost always pays to replace with a newer ballast. Options include T-12 energy-efficient magnetic, T-12 electronic, T-8 magnetic, or T-8 electronic.
- Luminaire efficiency may be increased by 10% to 15% through the use of a specular imaging reflector retrofit. However, it should be noted that luminaire uniformity of distribution may be adversely affected.
- Delamp, leaving two lamps in each luminaire. (Caution: disconnect unused ballast from line). If delamping results in too low a lighting level, the lamps may be changed to F40T10 or F40T12/EO lamps, or specular imaging reflectors may be added to the luminaires.

Figure 10 shows examples of how footcandles can still be kept at a workable level by using delamping and reflector strategies. If delamping results in too low a light level, the situation may be remedied with the use of T-10 or T-12/EO replacement lamps.

Guideline Specifications

Specification of energy-saving fluorescent lamps and ballasts is not difficult. Most of the products are now generally offered through major electrical distributors across the U.S. In the case of T-8 lamps, many luminaire manufacturers consider T-8 technology to be a standard option.

Lighting Fixture Schedules

Most lighting designs list fixtures by type or "tag" in a schedule. This schedule often contains all information needed for lamps and ballasts. To properly specify fluorescent lamps, however, it is recommended that a few special notes be included to clarify the designer's intent. Please refer to

Figure 10
Results of Delamping 2' x 4' Troffers

Action	Lamp-Ballast System	Footcandles (RCR=5)	Footcandles (RCR=1)
None (Base Case)	4-F40T12-Magnetic	66	88
Delamp	2-F40T12-Magnetic	36	48
Delamp	2-F40T12-Electronic	33	45
Delamp/Reflect.	2-F40T12/ES-Magnetic	38	52
Delamp/Reflect.	2-F40T12/ES-Electronic	37	50
Delamp	F40T10-Magnetic	43	58
Delamp/Reflect.	F40T10-Magnetic	50	68
Delamp/Reflect.	F40T12-EO-Magnetic	46	62
Delamp	F32T8-Magnetic	34	46
Delamp	F32T8-Electronic	34	46
Delamp/Reflect.	F32T8-Magnetic	39	53

Notes:
1. Delamping alone produces 10% improvement in relative light output due to improved thermal application factor and lower lumen absorption by lamps.
2. Delamping combined with reflector produces 15% improvement in relative light output.
3. Improvements greater than 15% achieved by use of more efficient lamp-ballast technologies.

the suggested "Lighting Fixture Schedule" (Figure 11).

Using lighting fixture schedules is an excellent method to properly specify lamps. There are several reasons:

- Lighting fixture schedules are used to quickly identify luminaires.
- Lighting fixture schedules contain most of the necessary information for complete specification of lighting on most projects.
- Contractors and distributors are more likely to read a lighting fixture schedule, whereas written specifications are seldom read or referred to, except by the contractor's office personnel.
- Highly detailed lighting fixture schedules reduce the possibilities of substitution of inferior goods.

Standard Specifications

Most commercial projects use variations of standardized specifications from the Construction Specifications Institute (CSI) recommended format. This shorter specification format is better for smaller, less complex projects. It contains all the basic information to assure proper provision of the required lamps.

Specifiers should be diligent, as minor cost differences and "value engineering" may be used to substitute standard T-12 lamps for more energy-efficient advanced products.

A Recommended Basic Specification

The following specification is intended for a typical job calling for T-8 lamps with electronic ballasts. See the *Energy-Efficient Fluorescent Ballasts* guideline for a sample specification for electronic ballasts.

Fluorescent Lamps

1. Meet applicable sections of ANSI C82 and C78.
2. In general, lamps shall be 265 mA "T-8" rapid start type as follows:
   - a. 2' lamps shall be 17-watt F17T8
   - b. 3' lamps shall be 25-watt F25T8
   - c. 4' lamps shall be 32-watt F32T8
   - d. 5' lamps shall be 40-watt F40T8
   - e. 1' MOL U-lamps shall be 16-watt FB16T8
   - f. 1.5' MOL U-lamps shall be 24-watt FB24T8
   - g. 2' MOL U-lamps shall be 31-watt FB31T8
3. Color: lamps shall be (3000)(3500)(4100) Kelvin correlated color temperature.
4. Color rendering index: lamps shall have a minimum CRI of (70)(80) through the use of (RE-70)(RE-80) rare earth phosphor coatings.
5. Lumen output, lamp life, and lumen depreciation, as a function of mean lumens, shall be determined in accordance

Figure 11
Sample Lighting Fixture Schedule

Tag	Description	Lamps	Ballast Description	Voltage	Input Watts	Product
F1	2' X 4' Parabolic Troffer, 18 cell floating door semi- specular 3-inch deep louver heat extract air handling NEMA G tandem ballasted pairs per Title 24	(3)F32T8/RE735	Magnetic Energy-efficient (1) two-lamp in "slave" and (2) two-lamp in "master"	277	100	LLL 123/ES PAIR
F1A	Same as F1	Same as F1	Magnetic energy saving (1) two-lamp and (1) one-lamp	277	103	LLL123
F2	2'X 2' Parabolic troffer 16 cell floating door specular 4-inch deep louver static NEMA F	(2)FB31T8/RE735	Electronic instant start type ABC 123 (2) lamp ballast	277	90	LLL234

General Requirements:
1. Lamps and ballasts shall meet applicable standards of the American National Standards Institute (ANSI), National Electrical Manufacturers Association (NEMA), and Underwriters Laboratories (UL). Luminaires shall be UL listed, or listed by other recognized testing agency. Ballasts and other materials shall be UL listed or recognized as appropriate and shall meet California energy standards.
2. Electronic ballasts shall be manufactured by __________ (list approved manufacturers) and shall be warranted for 3 years, including material cost and labor allowance.
3. Lamps shall be made by __________ (list approved manufacturers). Do not mix manufacturers of same type lamps.
4. (Insert any special project requirements here.)

with IESNA testing procedures and according to the ratings published in (Manufacturer's Name) Catalog.

6. Replace defective lamps occurring within 90 days of beneficial occupancy.
7. Approved manufacturers (list).
8. No substitutions shall be made without prior approval.
9. Any other project-specific data.

Extensive Specifications

CSI recommends that more extensive technical specifications be written for complex projects or projects being built overseas. Although significantly longer and more work for the specification writer, these specifications protect against substitution with inferior "knock-off" products made by manufacturers over whom the designer has no influence. At present, world-wide specifications are reasonably standard. However, the cost or unusual nature of advanced technology lamps may be a cause for substitution with the less efficient T-12 lamps. Well-written specifications can reduce the likelihood of this occurring.

Manufacturer/Product References

Manufacturer	Products
General Electric	Lamps, most types
Mitsubishi	Lamps, some types
OSRAM Corporation	Lamps, most types
Panasonic	Lamps, most types
Philips	Lamps, most types
Sylvania	Lamps, most types

(Inclusion in this list does not imply applicability or endorsement by the California Energy Commission, the U.S. Department of Energy, or the Electric Power Research Institute. Additional companies may also manufacture these products.)

against substitution by inferior, knockoff products made by manufacturers over whom the designer has no control.

Most products offered on the U.S. market have foreign counterparts. However, the systems of nomenclature differ. Also, the different operating voltages and frequencies of foreign electrical systems make it necessary to use totally different integral and modular components.

Manufacturer/Product References

Lamps (Most Types)	Electronic Ballasts	Magnetic Ballasts
General Electric	Advance Transformer	Advance Transformer
Mitsubishi	Electronic Ballast Technology	Magnetek Universal
OSRAM Corporation	ETTA Industries	Quality Services Electronics
Panasonic (Matsushita)	Innovative Industries	Radionic
Philips	Lutron Electronics	Robertson
Sylvania	Magnetek Triad	Schumacher
	OSRAM Corporation	Valmont Electric
	Valmont Electric	

(Inclusion in this list does not imply applicability or endorsement by the California Energy Commission, the U.S. Department of Energy, or the Electric Power Research Institute. Additional companies may also manufacture these products.)

Compact Fluorescent Lamps

California Energy Commission
Building and Appliance Efficiency Office

1993 Advanced Lighting Guidelines March 1993

Introduction

The continuing rise in the popularity of compact fluorescent lamp technology is good evidence of its value as an energy-efficient, long lasting substitute for the incandescent lamp. The average compact fluorescent lamp consumes only one-quarter to one-third as much energy as its incandescent counterpart and will last up to ten times longer. For example, a 10,000 hour, 13-watt compact fluorescent lamp (about 17 watts with the ballast) will provide about the same illumination as a 60-watt incandescent lamp that has a life of approximately 1000 hours.

Compact fluorescent lamps are available in a wide range of color temperatures, from 2700 K to 5000 K. They have very good color rendering properties, and they are available in a variety of sizes, shapes, and wattages. The increasing availability of luminaires designed for compact fluorescent lamps – in both new and remodel applications – means that compact fluorescent lamps can meet most any design application requirement.

Compact fluorescent lamps were developed in the late 1970s and introduced to the U.S. market in the early 1980s. Early model lamp production concentrated primarily on the retrofit market. Integral lamp-ballast combinations with screw-in Edison bases provided a convenient and inexpensive alternative to traditional incandescent lamps for hotels, apartment complexes, and other high volume users. Modular systems with replaceable lamps were popular, as well. By the late 1980s, the popularity of compact fluorescent lamps had risen substantially. Relatively recent large-scale production of dedicated compact fluorescent luminaires has extended the range of applications for this technology.

Contents

Technology Description

Compact fluorescent lamps are actually lighting systems consisting of a lamp (often with a starter integrated into the base), a lamp holder, and a ballast. Sometimes, a screw-in socket adapter is incorporated into the package. Generally, there are three different types of compact fluorescent lamp-ballast systems (see Figure 1):

- *Integral systems* are self-ballasted packages and are made up of a one-piece, disposable socket adapter, ballast, and lamp combination.

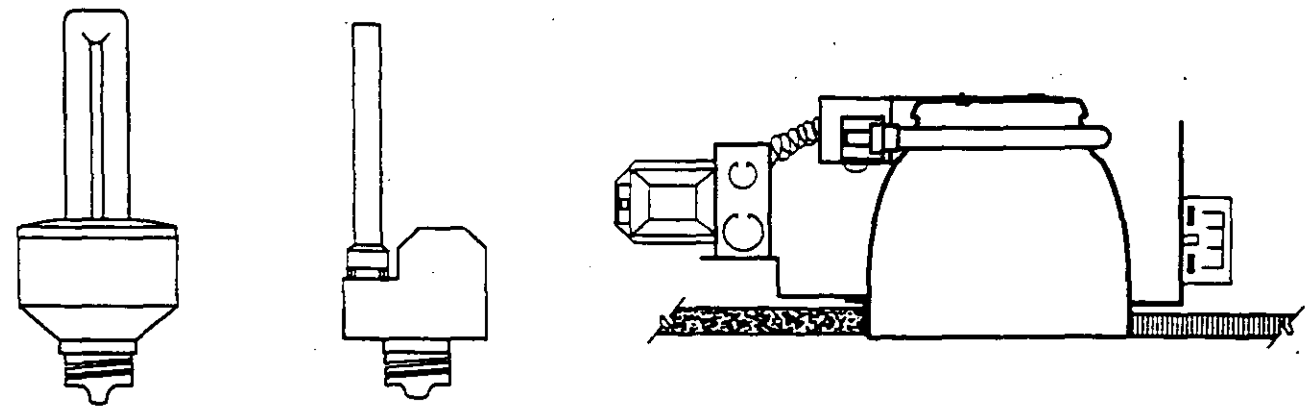


Figure 1
Compact Fluorescent Lamp-Ballast Systems

- *Modular systems* are also self-ballasted packages, consisting of a screw-based incandescent socket adapter, ballast, lamp holder, and replaceable lamp.
- *Dedicated systems* exist when a ballast and fluorescent lamp socket have been directly wired in as a part of the luminaire. While integral and modular systems are designed to screw into existing incandescent medium base sockets, dedicated systems generally are OEM (Original Equipment Manufacturer) components, supplied with luminaires.

Lamps are easily replaceable in both modular and dedicated compact fluorescent systems. On the other hand, relamping in an integral system requires the replacement of the entire integral unit.

Modular and integral compact fluorescent systems have particular relevance in remodel and retrofit applications. Dedicated systems are designed primarily for new construction purposes, although dedicated hardwire retrofit kits for downlights have been introduced recently by several companies. Simple permanent conversion kits for exit signs and table lamps are also available.

Lamp Types

The following lamp types are commonly available from a number of manufacturers.

- T-4 diameter twin-tube two-pin lamps have a starter built into the lamp plug base. They operate on inexpensive reactor ballasts, come in wattages from 5 to 13 watts and are available for both modular and dedicated systems.
- T-4 and T-5 diameter quad-tube two-pin lamps also have plug bases and built-in starters. These lamps produce more light than simple twin-tubes and are available up to 27 watts. These lamps are available for all compact fluorescent systems.
- Both T-4 and T-5 diameter twin-tube and quad-tube lamps are now available in four-pin versions that do not contain a starter in the base of the lamp. These lamps are

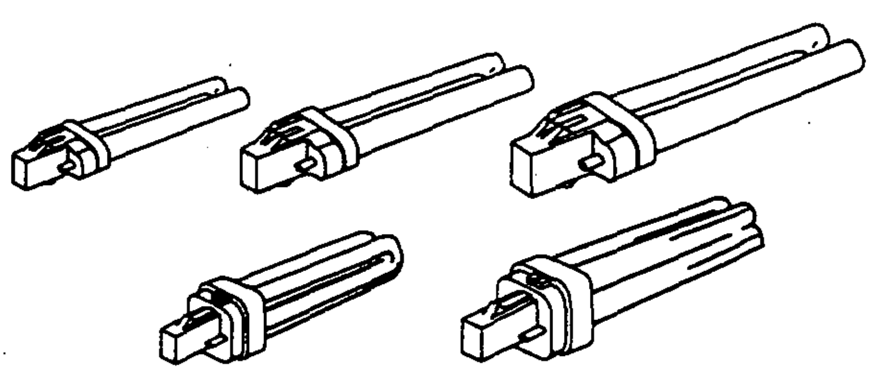


Figure 2
Common Compact Fluorescent Lamp Types

designed primarily for use with electronic ballasts. Larger T-5 lamps with 2G11 bases are discussed in the *Full Size Fluorescent Lamps* guideline.

Compact fluorescent lamps for self-contained integral systems. are generally a twin or quad-tube integrated with a ballast and screw-in socket base. In some cases a reflector or surrounding diffuser may be included in the package.

Ballasts

Compact fluorescent lamps are discharge lamps requiring ballasts to start and operate properly. A ballast provides the necessary voltage to start the lamp and, once started, keeps the lamp in operation. Ballasts also consume energy that must be accounted for when determining the efficacy of a particular lighting system.

Integral and modular compact fluorescent systems combine an Edison screw base with a ballast for direct retrofitting of incandescent luminaires. All other compact fluorescent lamps are designed to have an external ballast that must be specified for each individual lamp type and wattage. Ballast options for compact fluorescent lamps are listed below.

Normal Power Factor (NPF) Reactor Ballasts

NPF ballasts are common for the smaller two-pin lamp sizes. The 120 volt version is generally the least expensive and most compact type. These ballasts exhibit very low power factors (.45 for 120 volt, 0.25 for 277 volt), so it is important for engineers to calculate circuit loading carefully when designing the electrical distribution system.

High Power Factor (HPF) Reactor Ballasts

Also for the smaller preheat lamps, these ballasts contain capacitors to raise the power factor to 0.90 . They are more expensive and larger than the NPF type, but they allow for conventional branch circuit design and lower installation costs.

Conventional Electromagnetic Energy Saving Ballasts

The higher wattage lamps designed for 2G11-based four-pin operation generally operate on single or multiple lamp ballasts similar to those used for standard fluorescent lamps. Most ballasts are the "energy-efficient" type, consistent with California and national ballast standards.

Dimming Ballasts:

The starterless four-pin lamps can be used with either a magnetic dimming ballast with appropriate wall box dimmer, or a special electronic dimmer and electronic dimming ballast. Check with the manufacturer.

Electronic Ballasts

Several integral products are now available that combine a twin or quad-tube lamp with an electronic ballast. These products eliminate the objectionable starting flicker that has been associated with compact fluorescent lamps with integral starter bases.

In addition to electronically-ballasted integral products, several manufacturers now offer compact fluorescent luminaires with electronic ballasts instead of standard magnetic ballasts.

Electronic ballasts for compact fluorescent lamps offer several advantages over standard electromagnetic ballasts:

- The system efficacy (lumens per watt, including ballast losses) is generally about 20% higher with an electronic ballast. Under test conditions of 25 °C (77 °F), the efficacy of an electronically-ballasted compact fluorescent lamp ranges from 50-70 lumens/watt, compared to 40-55 lumens/watt for a magnetically-ballasted compact fluorescent lamp.
- The starting time of electronically-ballasted lamps is generally less than one second, while magnetically-ballasted lamps typically require one to four seconds to start.
- Electronic ballasts reduce lamp flicker.
- Electronic ballasts generally operate much more quietly than magnetic ballasts.
- Electronic ballasts can be manufactured in much smaller sizes and are lighter than conventional magnetic ballasts.

A disadvantage of electronic ballasts for compact fluorescent lamps is their higher price. This is compounded by the fact that there are few electronically-ballasted modular type compact fluorescent systems where the lamp can be replaced separately from the electronic ballast. Integral electronic designs require that the ballast be disposed of with the lamp. In addition, many of the current products exhibit a high percentage of total harmonic distortion (THD). The effects of THD produced by compact fluorescent lamp ballasts is still being evaluated by utilities, but it appears that the actual harmonic current is insufficient to cause major concern.

Power Quality Issues

Low power factor is one indicator of the effect that compact fluorescent lamps can have on the power quality of a utility distribution system. Compact fluorescent systems generally have power factors much lower than the 90% level achieved for high quality ballasts in typical full-size fluorescent lighting systems. Power factor is a performance measure that determines how effectively input current is converted into actual usable power delivered to the lamp. Optimum power utilization would result in a power factor of 1.0, meaning that the product of voltage and the current (volt-amperes or VA) is equal to the power used. Most compact fluorescent lamp systems, regardless of whether they are magnetically or electronically ballasted, are supplied with NPF ballasts, rated between 0.50 and 0.70 at 120 volts, and as low as 0.21 at 277 volts. Thus, a 13-watt lamp drawing a total load with ballast of 17 watts at a power factor of 0.50 actually draws 34 VA at 120 volts– twice as much current as it would with a power factor of 1.0. Branch circuit current and overcurrent protection are based on VA. This makes it important to consult with a utility representative or professional engineer when using large numbers of NPF ballasted compact fluorescent luminaires.

High power factor ballasts for compact fluorescent lamps are available, but in most cases, luminaire manufacturers offer them only as optional add-on features. Utility-sponsored energy efficiency programs encourage the use of HPF ballasts, so they should become increasingly available in the near future. Whether using HPF or NPF ballasts, building engineers should follow the input current instructions of each ballast when designing the circuit loading.

Harmonic distortion is another indicator of the effect of compact fluorescent lamps on power quality. Any non-linear load, such as a personal computer, variable speed motor, television, or compact fluorescent lamp, causes harmonic distortion in power distribution systems. Most magnetically-ballasted CF lamps have a THD between 15% and 25%. The THD from most available electronically ballasted compact fluorescent lamps may be significantly higher, due to severe distortion of the current wave form. Distortion of the sinusoidal wave form may also be associated with a reduced power factor. A second potential concern is the presence of third (180 Hz) harmonics. In principle, these harmonics may cause overheating on the neutral line of three phase systems in older commercial buildings. This generally is not a practical problem for compact fluorescent lamps, because of the relatively small size of the load imposed by these lamps.

There are products currently available that reduce both the THD and the odd harmonics from electronically-ballasted lamps to levels approaching those of magnetic ballasts. Electronically-ballasted integral lamp-ballast packages with high power factors and low THD are currently available. However, increased size requirements, increased radio frequency interference (RFI), and cost factors have slowed the development of similar products. Utility energy efficiency programs are expected to encourage the mitigation of harmonic distortion problems, and low harmonic distortion ballasts for compact fluorescent lamps should become increasingly available in the near future.

For further information on ballasts, harmonic distortion, and other power quality issues, see the *Energy-Efficient Fluorescent Ballasts* Guideline.

Dimming

In general, compact fluorescent lamps cannot be dimmed using conventional dimming equipment. For example, according to at least one lamp manufacturer, using conventional incandescent dimmers in an attempt to dim integral units – especially those using electronic ballasts – can cause a fire. However, there are two specific products that enable dimming of compact fluorescent lamps:

- Dimming adapters permit an incandescent dimmer to dim a four-pin quad-tube lamp. The adapter must be used with a specific ballast that is factory-installed on the luminaire.
- Solid state dimming ballasts permit the dimming of four-pin twin-tube and quad-tube lamps with a remote potentiometer or low voltage signal.

Switching

The longevity of any fluorescent lamp, including compact fluorescents, is affected by the number of times the lamp is switched on and off during its life. Fluorescent lamp life ratings listed in lamp manufacturers' catalogs are based on a specific switching cycle of 3 hours on per start. Fluorescent lamp life may be less than the rated value if the lamp is switched more frequently than this. However, with electronic ballasting technology, manufacturers can include circuitry that optimizes the starting sequence (so-called "soft-starting"), thus preserving manufacturers' rated lamp life even if the lamp is switched more frequently than every 3 hours. The manufacturer should be contacted for more information if the application calls for frequent switching.

Of special concern are modern electronic control products. Devices such as wallbox touch switches, wallbox time switches, and wallbox occupant sensors may not be compatible with most compact fluorescent lamps. Incompatibilities are usually caused by the use of solid-state switches (triacs) instead of air gap switches or relays. A small continuous current (insufficient to illuminate an incandescent lamp) passes through the load even when it is "off." In magnetically-ballasted compact fluorescent applications, this idling current can cause continuous electrode heater and starter operation, resulting in reduced lamp life. In electronically-ballasted applications, the ballast may prevent idle current, in turn rendering the control device inoperable.

Environmental Conditions and Efficacy

It is important to realize that laboratory environmental conditions under which lumen output ratings are made are often quite different from actual installation conditions. The two environmental conditions that most significantly affect the performance of compact fluorescent lamps are ambient air temperature and the orientation or burning position of the lamp.

Figure 3 gives typical performance curves showing how ambient temperature affects lumen output of compact fluorescent lamps in both base up and base down burning positions. Note that while the compact fluorescent lamp produces rated lumens at 25 °C (77 °F) with the lamp base up, its lumen output drops to 80% of its rated lumens at 50 °C (122 °F). In applications where compact fluorescent lamps are mounted in small volume fixtures with a lack of air circulation (such as in lensed downlights), the user should expect that the ambient temperature would be between 40 °C and 50 °C (104 °F-122 °F), and should lower the lamp lumen rating accordingly. Some compact fluorescent luminaire manufacturers provide luminaires designed to improve ventilation in order to lower ambient air temperature and increase lumen output.

Figure 3 also shows how lamp orientation (burning position) can have a major influence on lumen output of a typical compact fluorescent lamp. Under identical ambient temperatures (25 °C [77 °F]), a compact fluorescent lamp in a horizontal or base up orientation will produce about 20% more lumens than a lamp in a base down position. As such, in any application where a compact fluorescent is used in a base down position (such as in a retrofit of an incandescent table lamp), the expected lumen output should be lowered by at least 10%. At higher ambient temperatures, a lowering of 15% is appropriate for base down operation. Manufacturers data should be consulted for specific values for individual lamp types, as performance differences are related to lamp shape and wattage.

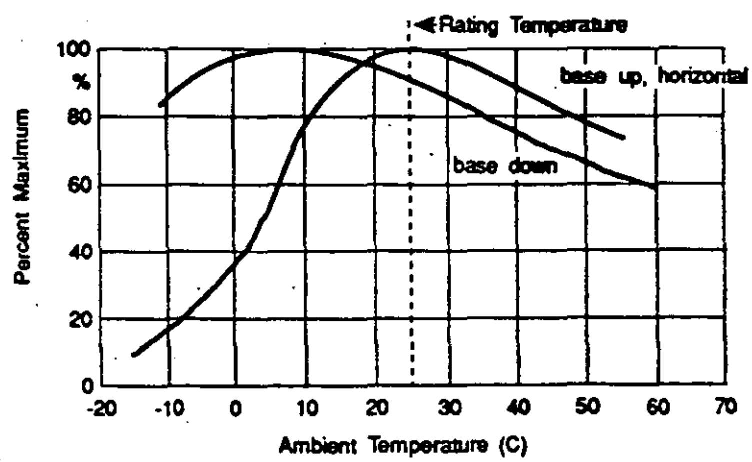


Figure 3

Typical ambient temperature and lamp orientation effects on lumen output of compact fluorescent lamps. Curves shown are for one specific lamp type in a draught-free environment. Performance – particularly in the base down position – will vary significantly depending on lamp configuration and wattage. (Source: Osram Corporation)

Current Products

As stated previously, compact fluorescent lamps are highly efficacious, have very good color rendering capabilities and are available in several color temperatures. Their performance is due to the use of high efficacy, high color rendering rare earth (RE) phosphors. The relative balance among these phosphors determines the color temperature of the lamp. RE phosphors are essential to the operation of the compact fluorescent lamp because of the high power density in the small diameter tube. The same loading of conventional halophosphors would result in rapid and severe lamp lumen depreciation.

Most compact fluorescent lamps are capable of generating about 50-60 lumens/watt. Their advantages notwithstanding, compact fluorescent lamps have similar overall efficacy as several other technologies of equal lumen output, such as low wattage metal halide and high pressure sodium lamps, and conventional straight, U-shaped, or circular fluorescent lamps.

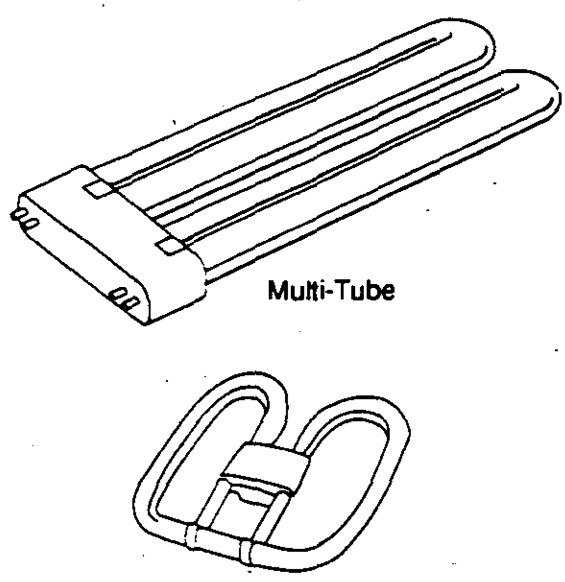


Figure 4
New Compact Fluorescent Lamp Products

New Lamp Products

In addition to the familiar types of compact fluorescent lamps, several new lamp configurations are becoming available. A new square-shaped "double-D" configuration is now available in three sizes and five different wattages. Its compact shape and size make it suitable for low profile surface and small recessed luminaires.

One lamp manufacturer is now producing a T-2 diameter, sub-miniature, wedge base fluorescent lamp in a wide range of lengths and wattages. It is available in both hot and cold cathode versions. As is true with all compact fluorescents, these lamps use RE phosphor coatings for good color rendering. T-2 lamp efficacy is more than 80 lumens/watt, exclusive of ballast losses. At this time, ballast and luminaire development for these lamps has been slow, thus limiting their application. Suitable applications for this lamp will probably include task, sign, and showcase lighting.

Several manufacturers are now offering compact fluorescent lamps consisting of three bent tubes (as opposed to single and quad tube configurations). This allows for more lumens in a smaller package. For example, one manufacturer has begun producing an electronically-ballasted 20-watt compact fluorescent, with high power factor and low THD. This package is only 6 inches long, and it produces similar lumens as a 75-watt incandescent lamp.

Current research into new compact fluorescent lamp configurations is concentrated on more varieties of lamps with higher powers, different shapes, and single-ended, four-pin bases (2G7, 2G11, etc.). These lamps can use electronic ballasts, can be dimmed, and will eliminate much of the starting flicker that has been associated with the use of compact fluorescent lamps. This development promises to increase the number of compact fluorescent lamp applications.

Compact Fluorescent Luminaire Design

The exciting energy-saving possibilities of compact lamp luminaires have caused many manufacturers to rush products to market that are simply incandescent luminaires with fluorescent sockets. Specifiers should be cautious of the following potential problems:

- Use of reflectors and other hardware originally intended for incandescent lamp configurations (luminaire efficiency problem)
- Overheating, which causes short lamp and ballast life and reduced lumen output (luminaire design problem)
- Ballasts and lamps making acoustic noise (luminaire and application problem)
- Unusually low or high bulb wall temperature causing significant departure from rated lamp lumens (luminaire design and application problem)
- High THD, low ballast factor, and low power factor of particular lamp-ballast combinations (See also the *Energy-Efficient Fluorescent Ballasts* guideline)

Luminaire Types

Lower wattage compact fluorescent lamps are designed to be used in place of incandescent lamps in a wide variety of luminaire shapes and types. The twin-tube style is especially good for task lights, wall sconces, exit signs, step lights, and exterior path lighting. Two-lamp, horizontally aligned, twin-tube combinations have become an excellent substitute for incandescent recessed downlights, and many manufacturers of recessed luminaires have designed series of luminaires around this concept. The quad-tube lamp has similar applications as a downlight, wall washer, and sconce light.

Figure 5 illustrates some luminaires that use compact fluorescent sources.

Retrofitting

Modular and integral compact fluorescents systems with Edison screw-in sockets are generally not as efficient as their dedicated counterparts, but they do offer a means to upgrade existing incandescent lighting. Modular and integral lamps are available with either an electronic or magnetic ballast. The electronic ballast operates at a higher efficiency and without noise or flicker.

Application Guidelines

In general, compact fluorescent lamps are best applied in situations where incandescent or other small fluorescent lamps would be considered. They may be used in a wide variety of residential, commercial, retrofitting and new construction applications.

Incandescent Lighting Alternatives

Compact fluorescent lamps can generally be utilized in many areas where incandescent lamps would typically have been used before. Such areas can include recessed downlights, wall washers, desk lights, wall sconce type ambient fixtures, under cabinet fixtures, landscape lights, residential floodlights, and a variety of other applications. In most instances, compact fluorescent lamps produce three to four times more lumens per watt than incandescent lamps. For example, a 13-watt compact fluorescent will provide approximately the same light as a 40 to 60-watt incandescent lamp.

Retrofitting incandescent lighting with compact fluorescents offers significant cost savings to the user. Money saved through reduced energy use, fewer lamp replacements, longer lamp life, and related maintenance savings can quickly recoup the initial investment and provide continuing operating cost savings. Additionally, initial retrofit costs are often partially offset by utility rebates.

Alternatives to Other Fluorescent Lamps

In the lower wattages, other smaller fluorescent lamp types, such as circline configurations, lack the convenient single-ended plug base, color temperature options, and consistent good color rendition of compact fluorescent lamps. Many typical fluorescent applications for smaller lamps, such as task lights, surface mounted "drum lights," and corridor lights, will be more effective if compact fluorescent lamps are used. Also, the high color rendering quality of the compact lamp is maintained with every lamp replacement. See Figure 6 for more information on the color options and characteristics for compact fluorescent lamps.

Figure 5

Compact Fluorescent Luminaire Applications

	Recessed Downlights	Surface Units	Pendants	Sconces	Floodlights	Exit & Sign Lighting
T-4 Twin-Tube	○	○	○	●	●	●
T-4 Quad-Tube	● (a)	○	○	●	●	○
Globe Shaped Unit	○	○	●	--	--	--
Integral Lamp-Ballast	○	--	●	--	--	--
Reflector Unit	○	--	○	--	--	--
Electronically-Ballasted Integral Unit	○	○	●	○	○	--
Square	●	●	○	○	--	○

Key

● Superior Lamp Choice

○ Suitable Lamp Choice

-- Inappropriate Lamp Choice

Note:

a. with conversion kits complete with reflector

Figure 6

Color Options of Standard Compact Fluorescent Lamps

Color Temperature	Nominal CRI	Matches
2700 K	82	Warm White, Incandescent, White HPS
3000 K	85	Warm White, Incandescent, Halogen, Other 3000 K Fluorescent and HID lamps
3500 K	85	Halogen, Other 3500 K Fluorescent lamps
4100 K	85	Cool White, Metal Halide, Other 4100 K Fluorescent and HID lamps
5000 K*	85	C/D50 and all other high color temperature Fluorescent and HID sources

* not as many products available as other color temperatures

Limitations

Overall, compact fluorescent lamps are excellent choices for many residential and commercial lighting situations. The major limiting factor associated with compact fluorescent lamps in retrofit applications is their size. Compact fluorescent lamp-ballast packages are somewhat larger than incandescent lamps of the same lumen output, meaning that they may not fit properly in luminaires designed for incandescent sources. For example, in recessed downlights, a screw-in compact fluorescent package may protrude below the ceiling line, resulting in an objectionable appearance and creating glare. In addition, the base portion of a compact fluorescent lamp that contains the ballast is larger and of a different shape than the standard incandescent lamp. The luminaire's reflector may therefore not allow enough clearance for the adapter to be screwed into the socket. For these reasons, designers are encouraged to try out a test lamp of the intended configuration prior to attempting an entire retrofit. Many manufacturers of compact fluorescent lamps can provide sample products or cardboard templates that may be used to check for physical incompatibilities before purchasing.

Another limitation of compact fluorescent lamps is that they may not be suitable in very high ceilings (more than 12 feet), or in certain accent lighting applications requiring a tight beam spread or a point source sparkle. Additionally, the designer should be careful about using compact fluorescent lamps in exterior cold weather situations, as the operation of the smaller wattage lamps can be adversely affected by low temperatures (<0 °C [32 °F]) unless enclosed fixtures and/or electronic ballasts are used.

Residential Applications

In general, the use of compact fluorescent luminaires is especially appropriate for rooms such as kitchens and bathrooms, where high lumen output, good color rendering and adherence to local energy codes is required. Compact fluorescent lamps are also useful in all utility room lighting applications and in enclosed exterior fixtures (weather permitting) such as lanterns, and path lights. They are useful as ambient light sources in wall sconces. The extended lamp life of compact fluorescents makes them an intelligent design decision in hard-to-reach places. They are also appropriate for task lights, especially those types designed for the configuration of compact fluorescent lamps. A commitment to increased residential use of compact fluorescent lamps could be quite significant, in terms of energy conservation. A savings of 25% to 50% of the lighting electrical energy used by every home could be realized if all acceptable fluorescent applications were utilized. Figure 7 summarizes some of the residential applications suitable for compact fluorescent lamps.

The selection of compact fluorescent lighting equipment for residential design applications should be made carefully. Newer designs using electronically-ballasted compact fluorescent lamps are suitable for many residential applications, since these packages operate silently and start almost immediately without an initial flicker. An added benefit is the lighter weight and smaller size of the electronically-ballasted products. When magnetically-ballasted systems are used in residential applications, the benefits of energy efficiency and long life are sometimes outweighed by concerns for the acoustic noise of some ballasts, or by a negative reaction to starting flicker. In most residential applications, these conditions are not tolerable. In any case it is advisable to consult with and advise one's client about the overall benefits of compact fluorescent lighting.

Figure 7
Residential Applications for Compact Fluorescent Lamps

Kitchens	Living Rooms	Bedrooms	Bathrooms	Utility Areas	Exterior
Recessed downlights	Task lights	Task lights	Mirror lights	Stairways	Lanterns
Under cabinet lights	Swing arm lamps	Closet lights	Recessed downlights	Laundry rooms	Garage lights
	Under cabinet lights		Shower & tub lights	Attics	Path lights
	Recessed downlights			Closets	Security lights
	Wall washers			Crawlspaces	

Commercial Applications

Commercial lighting represents the best application for compact fluorescent technology. Compact fluorescent luminaires can be easily incorporated into lighting designs that are both aesthetically pleasing and energy efficient. It is now possible to design a first-class project using compact fluorescents in place of most incandescent lamps.

In office lighting design, not every incandescent luminaire has a compact fluorescent counterpart, but many do. Offices and other types of commercial and institutional spaces will look good and operate efficiently through the proper use of compact fluorescent troffers, downlights, wall washers, and task lights. As a result, designs will more easily comply with the applicable Title 24 standards contained in the California Code of Regulations. Incandescent lighting should be saved for a few key situations, such as locations where the wider dimming range of incandescent lamps is needed.

In retail lighting design, fluorescent light is appropriate for general illumination, wall washing, and some types of case lighting. The energy conscious designer uses standard incandescent or halogen sources only when point source sparkle or significantly more candlepower is required. Examples of this would include display lighting, jewelry case lighting, etc..

In restaurants and hotels, most of the circulation areas and other public spaces can be illuminated with compact fluorescent sources, unless ceilings are especially high, an application where HID sources might be more appropriate. Additionally, some pendant type luminaires and wall sconces can be equipped with compact fluorescent lamps. Incandescent lighting can then be used where it is especially important for full range dimming and special accents. Many fast food/fast action spaces can take advantage of the smaller general illumination fixtures made possible by compact fluorescent technology. In hospitals, laboratories, schools, and other institutions, compact fluorescent lamps can generally replace most incandescent applications.

In industrial lighting, most compact fluorescent lamps have limited applications. But the low heat of compact fluorescent lamps make them safer in hazardous environments where HID lamps might otherwise be used.

Figure 8 suggests some possible commercial applications for compact fluorescent lamps.

Figure 8
Commercial Applications for Compact Fluorescent Lamps

General Lighting	Accent & Specialty Lighting	Decorative & Portable Lighting	Utility Lighting	Exterior Lighting
Recessed downlights	Recessed & track-mounted wall washers	Wall sconces	Security lighting	Landscape floodlights
Suspended luminaires	Under cabinet lights	Chandeliers	Step lights	Pedestrian post top and bollard lights
Indirect lighting systems	Cove lights	Table & floor lamps	Exit signs	Step lights
	Case display lights	Makeup & dressing lights	Task lighting	Under rail lights
	Modular strip outlining			Vandal-resistant security lights
	Sign & display lights			

Examples

Cost Savings Retrofit Profile

Selling the idea of compact fluorescent lamps as effective, long lasting, energy saving replacements for incandescent lighting is much easier if the end user can see, in tangible terms, the benefits of such a strategy. Figure 9 shows one example of how a switch from incandescent to compact fluorescent lighting allows for significant energy savings and decreased operation costs. The table represents a hypothetical situation in which a facilities manager is considering a change from 75-watt incandescent downlights to 20-watt compact fluorescents with electronic ballasts. A total of 60 fixtures are involved.

Figure 9

Compact Fluorescent Retrofit Cost Savings Analysis

Existing Lamp: 75W A19/1210 Lumens	
Replacement Lamp: 20W Quad-Tube with Integral Electronic Ballast	
Existing Lamp Wattage	75
Replacement Lamp Wattage	20
Watts Saved/Lamp	55
Operating Hours/Year[1]	2600
kWh Savings/Year Per Lamp	143
Existing Lamp Rated Life	1,000 Hours
Replacement Lamp Rated Life	10,000 Hours (3.85 Years)
Electricity Cost/kWh[2]	0.12
Utility Savings/Year Per Lamp	$17.16
Savings Over Life of Lamp	$66.07
Relamping Cost of Existing Lamp[3]	$7.00
Avoided Cost of Relamping Over Lamp Life	$70.00
Relamping Savings/Year	$18.18
TOTAL YEARLY SAVINGS PER LAMP	**$35.34**
Cost of Retrofit[4]	$22.00
Utility Rebate[5]	$3.00
Net Cost of Retrofit Per Lamp	$19.00
Number of Fixtures	60
Total Cost of Retrofit	$1140.00
Payback Period	**6½ months**
Total Annual Savings	$2120.40
Net Savings Over Life of Lamps	$7023.54
Return on Initial Investment	186%

Notes:
[1] Based on 10 hours/day, 5 days/week
[2] Estimate, based on average commercial 1992 costs
[3] Estimate, includes lamp cost and labor
[4] Estimate, based on 1992 costs; includes integral lamp-ballast and labor
[5] Estimate, varies by region and utility company

General Downlighting

Many corridors and lobbies are furnished with six or eight-inch round or square recessed downlights for general or wall wash lighting purposes. Typical designs call for incandescent "cans" or "tophat" luminaires. An energy-efficient alternative is to use modular type downlights designed specifically for compact fluorescent twin-tube or quad-tube lamps. By careful selection, the specifier can choose a fluorescent luminaire that appears similar to standard incandescent downlights.

A general rule-of-thumb is to use about 25% of the required incandescent lamp wattage. In other words, use a downlight with one 26-watt or two 13-watt lamps to replace a 100-watt incandescent lamp, two 18-watt lamps to replace a 150-watt incandescent lamp, and two 26-watt lamps to replace a 200-watt incandescent lamp. Avoid using screw-in socket adapters in new construction, as they are not as efficient and are easily compromised by incandescent relamping at a later time.

Energy efficiency with a compact fluorescent downlight system is significant when compared with incandescent options. For example, to provide 15-20 footcandles in a corridor, luminaires are installed about every 30 square feet. The fluorescent scheme (two 13-watt twin-tube lamps) operates at about 1.0 watts/ft^2, while the incandescent scheme (one 100-watt A lamp) operates at over 3 watts/ft^2. The savings of over 6 kWh/ft^2/y saves $0.60/ft^2/y, or about $18/y/fixture. Added benefits result from a much longer lamp life and fewer maintenance costs associated with replacements.

Outdoor Floodlighting

Compact fluorescent lamp sources have excellent floodlighting capabilities, and there is a significant potential for savings over the use of traditional incandescent sources. Many floodlighting schemes for shorter walls, signs, etc. use an incandescent PAR-38 flood lamp. In many situations, a short fluorescent flood lamp luminaire will serve as an energy saving option, as long as ambient temperatures are high enough for proper operation. For example, a 22-watt quad-tube compact fluorescent luminaire with reflector would be a good alternative to an incandescent luminaire, supplied with a 100-watt PAR-38 lamp. The 22-watt quad-tube luminaire would use 60 watts less (including ballast) than a 90-watt PAR halogen lamp and 70 watts less than a standard 100-watt PAR lamp.

Decorative Lighting

Many pendant lights, wall sconces, and other types of decorative luminaires are available as compact fluorescent lamp sources. Manufacturers of wall sconces in particular have been quick to capitalize on the technology of compact fluorescent lamps, and many products are available.

Product Classifications

Lamp manufacturers tend to create "marketable" product names and identifications. These names make for better marketing, but make it more difficult to write a generic specification. However, the National Electrical Manufacturers Association (NEMA) has developed a generic designation system for non-integral compact fluorescent lamps. In most cases the specifier can easily relate the desired lamp product to the NEMA code. The code consists of the following elements:

CF + (Shape) + (Wattage) +(Base Designation)

The shape designator may be "T" (twin-tube), "Q" (quad-tube), "S" (square shape), or "M," for any configurations not covered by the other designators. Base designators, on the other hand,

Figure 10

Performance Characteristics of Two-Pin Twin-Tube and Quad Tube Compact Fluorescent Lamps

NEMA Lamp Code	System Input Watts (typical)	Rated Lumen Output	Typical Ballast Factor 120v	Actual Lumen Output	Ballast Type	Rated System Efficacy (L/W)
CFT5W/G23	9	250	.95-1.0	238-250	5W Reactor[5]	26-28
CFT7/G23[1]	11	400	.89-.90	356-360	7W Reactor[5]	32-33
CFT9W/G23[1]	13	600	.79-.83	474-498	9W Reactor[5]	36-38
CFT13W/GX23[1]	17	900	.95-1.0	855-900	13W Reactor	50-53
CFQ9W/G23	13	600	.79-.83	474-498	9W Reactor[5]	36-38
CFQ13W/GX23[2]	17	860	.95-1.0	817-860	13W Reactor	50-53
CFQ10W/G24d	16	600	.90-1.0	540-600	10/13W Auto.[3]	34-38
	13				10/13W React.[4]	42-46
CFQ13W/G24d	18	900	.90-1.0	810-900	10/13W Auto.[3]	45-50
	16				10/13W React.[4]	51-56
CFQ18W/G24d-[2]	25	1250	.90-1.0	1125-1250	18W Autotrans.[3]	45-50
	22				18W Reactor[4]	51-57
CFQ26W/G24d[2]	37	1800	.90-1.0	1620-1800	26W Autotrans.[3]	44-49
	31				26W Reactor[4]	52-58
CFQ15W/GX32d	20	900	.90-1.0	810-900	16W Reactor	41-45
CFQ20W/GX32d	27	1200	.90-1.0	1080-1200	22W Reactor	40-44
CFQ27W/GX32d	34	1800	.90-1.0	1620-1800	28W Reactor	48-53

Notes:
1 Most common lamps when standard twin-tube lamps are specified.
2. Most common lamps when standard quad-tube lamps are specified.
3. 120v operation
4. 277v operation
5. Multi-wattage ballasts available, but may result in low lumen output and shortened lamp life.
All lamps are rated for 10,000 hours @ 3 hours per start.

are readily available from lamp manufacturers' catalogs.

Using the NEMA generic designation code, a 13-watt T-4 twin-tube lamp would be designated as:

CFT13W/GX23.

A two-pin 26-watt T-4 quad lamp, on the other hand, would be described as:

CFQ26W/G24d.

Performance of Compact Fluorescent Lamps

The following table is included to provide information of the performance characteristics of some of the more compact fluorescent lamps. Values are included for twin-tube and quad-tube lamps. Before using the tables, it is important to realize that manufacturers of modular compact fluorescent lamps will usually list the lumen output of the lamp-ballast system as the rated lumen output of the manufacturer's lamp. In actuality, the lumen output of the modular compact fluorescent system is usually less than the lamp's rated lumens, because the ballast factor (a measure of a particular ballast's performance) is generally less than 100%. In using the tables, lamp lumen ratings should be multiplied by the ballast factor to determine the actual lamp lumens. If the ballast factor is not considered, the system may supply less illumination than anticipated. In integral systems, in which the ballast and lamp are inseparable, the manufacturer will usually give the corrected lumen output and no correction factors need be applied.

Guideline Specifications

Specifying compact fluorescent lamps is not difficult. There are several ways to insure that the preferred lamps and ballast requirement are clear to suppliers to avoid the substitution of inferior products. The designer may specify products by using lighting fixture schedules or by writing standard or extensive specifications.

Lighting Fixture Schedules

Most lighting designs list luminaires by type or "tag" in a fixture schedule included with construction documents. This schedule often completely specifies the luminaires, lamps, and ballasts. To properly specify compact fluorescent lamps, however, it is recommended that slightly more information be contained in the schedule than is often the case with other types of lamp products.

As has been previously noted, each manufacturer tends to create marketable product names for its lamps, making specifications difficult. For that reason, it is recommended that the specifier use the NEMA generic lamp designations whenever possible. For integral compact fluorescent lamps, it is best to identify a single manufacturer that makes all lamp products and use that manufacturer's nomenclature throughout. This way, the competitive bidder can easily list his/her corresponding lamp numbers in a general letter of proposed substitution.

Occasionally, there may be a specific lamp type that is unique to the manufacturer. For example, at the time of this guideline's printing only one manufacturer makes the square-shaped "double-D" compact fluorescent lamp. In situations like this, it may help to separately identify and list the unique lamp by naming the manufacturer in the lamp specification column.

Standard Specifications

Most commercial projects use variations of standardized specifications based on the Construction Specifications Institute (CSI) recommended format. This shorter specification format is better for smaller or less complex projects. An example of this format follows.

Compact Fluorescent Lamps:

1. Rare Earth phosphor coating having a minimum CRI of 80 with a correlated color temperature of (2700) (3000) (3500) (4100), (5000) Kelvin, unless scheduled or noted otherwise.
2. Lumen output, rated lamp life, and lumen depreciation determined in accordance with IES testing procedures, and equal in performance to published values in (Manufacturer's Name) catalog.
3. Replace defective lamps occurring within 90 days of beneficial occupancy.
4. Approved Manufacturers: (List)

Extensive Specifications

CSI recommends that more extensive technical specifications be written for complex projects or projects which are being built overseas. Although significantly longer and more work for the specification writer, these specifications protect the design against substitution by inferior, knockoff products made by manufacturers over whom the designer has no control.

Most products offered on the U.S. market have foreign counterparts. However, the systems of nomenclature differ. Also, the different operating voltages and frequencies of foreign electrical systems make it necessary to use totally different integral and modular components.

Manufacturer/Product References

Lamps (Most Types)	Electronic Ballasts	Magnetic Ballasts
General Electric	Advance Transformer	Advance Transformer
Mitsubishi	Electronic Ballast Technology	Magnetek Universal
OSRAM Corporation	ETTA Industries	Quality Services Electronics
Panasonic (Matsushita)	Innovative Industries	Radionic
Philips	Lutron Electronics	Robertson
Sylvania	Magnetek Triad	Schumacher
	OSRAM Corporation	Valmont Electric
	Valmont Electric	

(Inclusion in this list does not imply applicability or endorsement by the California Energy Commission, the U.S. Department of Energy, or the Electric Power Research Institute. Additional companies may also manufacture these products.)

Tungsten-Halogen Lamps

California Energy Commission
Building and Appliance Efficiency Office

Technology Description

Tungsten-halogen lamps have a whiter, brighter light and generally have longer lamp life than conventional incandescent lamps. They are also much more compact, making smaller, more compact reflector and luminaire designs possible. Although the tungsten-halogen lamp cannot compete with fluorescent or HID lamps in terms of energy efficiency or lamp life, it offers superb color, brilliance, and control characteristics. For these reasons, tungsten-halogen lamps are extremely popular with lighting designers.

Lamp Operation

Tungsten-halogen lamps are incandescent lamps made more efficient by the addition of a halogen gas, usually iodine or bromine. This gas suppresses tungsten filament evaporation by a chemical regeneration process known as the "halogen cycle." During lamp operation, the halogen gas combines with tungsten molecules that have evaporated off the filament. The evaporated tungsten molecules are then redeposited onto the filament, instead of on the bulb wall. As a result, lamp lumen depreciation due to bulb wall darkening is practically non-existent. Depreciation does occur, due to filament degradation, but it is significantly lower than in other incandescent lamps.

Proper operation of the halogen regenerative process requires operation of the tungsten-halogen lamp at an extremely high temperature. This increases lamp efficacy slightly, but it also requires that tungsten-halogen lamps have special glass envelopes – usually quartz – that will withstand the high bulb wall temperature. Lamps whose bulb walls are made of quartz require special handling, as quartz materials are extremely sensitive to oils and dirt from human skin. Handling of quartz lamps with

Figure 7-1
The Energy Policy Act of 1992

The U.S. Energy Policy Act of 1992 (Public Law 102-486), signed into law by President Bush on October 24, 1992, contains energy-efficiency standards and other regulations that will preclude certain lamps from being manufactured or imported into the U.S. after a transition period. Under the Act, reflectorized incandescent lamps, such as standard R and non-halogen PAR lamps will not be permitted (Ellipsoidal reflector ["ER"] are exempt). Tungsten-halogen type reflector lamps are the only reflector lamps that will comply to the Act. The transition period for compliance lasts until October of 1995. There are several categories of exempted lamps.

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bare hands can result in bulb wall deterioration, significantly reduced lamp life, and/or premature lamp failure.

Lamp Configurations

Tungsten-halogen lamps are available in three basic configurations: double-ended; single-ended; and halogen capsule lamps.

Double-Ended Lamps

Figure 2
Double-Ended Tungsten-Halogen Lamp

Double-ended tungsten-halogen lamps are tube shaped. Most of the lamps in this category have tubes of small diameter: T-2½; T-3; T-4; T-6; and T-8. Double-ended tungsten-halogen lamps range from 45 to 2000 watts. These lamps typically have recessed single contact bases, one at each end of the lamp. Standard lamp life is generally around 2000 hours, and efficacy, at a low 15-25 lumens per watt, is fairly typical of incandescent lamps as a whole. However, efficacy can be increased to 32-38 lumens per watt by the application of infrared reflecting film to the bulb wall.

T-3 lamps are often used in contemporary chandeliers, wall sconces and torchieres. They offer high light output and are relatively inexpensive to purchase.

Single-Ended Lamps

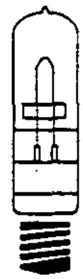

Figure 3
Single-Ended T-4 Minican Lamp

Single-ended tungsten-halogen lamps include a wide variety of sizes and characteristics. The one shared characteristic among these lamps is a single base at one end of the lamp. The most common base configurations are mini-candelabras, or "mini-cans," bayonets, bipins, and screw-ins. Lamp sizes range from T-3 to T-24, and wattages are from 5 to 10,000. In comparison with fluorescent and HID light sources, these lamps have short lamp lives (2000 hours), and low efficacy. However, at 20-25 lumens per watt, they are slightly more energy efficient than most incandescent lamps. IR-reflecting films are now available from at least one manufacturer of these lamps.

Single-ended tungsten-halogen lamps are commonly used in wall sconces, downlights and wall washers. The compact filament of this lamp type works especially well in complex optical systems, such as ellipsoidal reflectors and framing projectors.

Halogen Capsule Lamps

Tungsten-halogen capsule lamps include halogen PAR (Parabolic Aluminized Reflector) lamps, halogen PAR-IR (Infrared Reflecting) lamps, and low-voltage bud-shaped and projector type lamps, such as PAR-36, MR-11, and MR-16 lamps. Lamps designed to replace incandescent "A" lamps also fall into this category. This group of lamps contains a wide variety of lamp shapes, sizes, wattages, and base configurations. Although more efficacious than

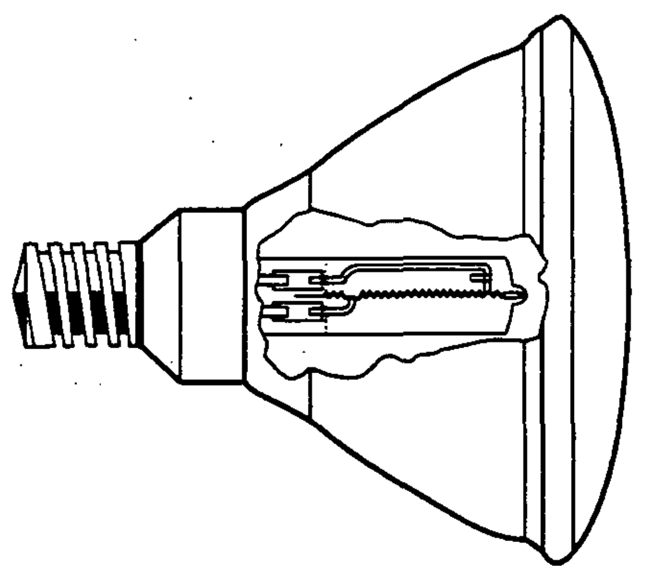

Figure 4
Cut-Away View Showing Tungsten-Halogen Capsule Within a PAR Lamp

incandescent lamps, this lamp family still falls far short of the energy efficiency provided by fluorescent and HID lamps.

Several varieties of tungsten-halogen capsule lamps can be called lamps within lamps: a small tungsten-halogen bud or capsule is mounted and sealed within a PAR or other type envelope. This makes it unnecessary to place a protective glass over the lamp, and in many cases, allows for greater beam control. See Figure 7-4.

Tungsten-halogen reflector lamps are generally used for accent and display lighting. Applications include lighting for restaurants, retail establishments, commercial displays, and artwork. The large, high-wattage PAR lamps can produce tremendous quantities of high quality light for these applications. The smaller low-voltage projector type lamps, on the other hand, are especially effective in design applications requiring compact track and recessed sources with more subtle illumination characteristics.

Infrared Reflecting (IR) Film Lamps

Up to 90% of the energy radiated by incandescent lamps, including tungsten-halogens, is invisible infrared (heat). However, some of this IR energy can be indirectly converted to light through the application of a dicroic film coating to the tungsten-halogen lamp (or capsule, in the case of PAR lamps). This coating consists of several layers of a micron-thin optical material. The coating reflects heat energy back onto the lamp filament while allowing visible light to pass through the bulb wall. The reflected infrared, in turn, further heats the tungsten filament. As a result, the necessary operating temperature for the halogen cycle is maintained with less input power. See Figure 7-5.

IR-reflecting lamps offer all of the benefits of standard tungsten-halogen lamps, including low lumen depreciation and high quality light. Tungsten-halogen lamps with infrared-reflecting films are presently offered in three configurations: single-ended T-4 lamps; double-ended, higher wattage T-3 quartz lamps (listed in Figure 7-5); and halogen PAR lamps. The energy savings potential with the double-ended and PAR lamp configurations is spectacular: a direct replacement of a standard incandescent lamp will, in some cases, reduce the wattage by 30% to 50% with no visible difference in light output or quality, though lamp cost is appreciably higher. However, the IR-reflecting single-ended quartz lamps offer no efficacy improvements over standard incandescent lamps.

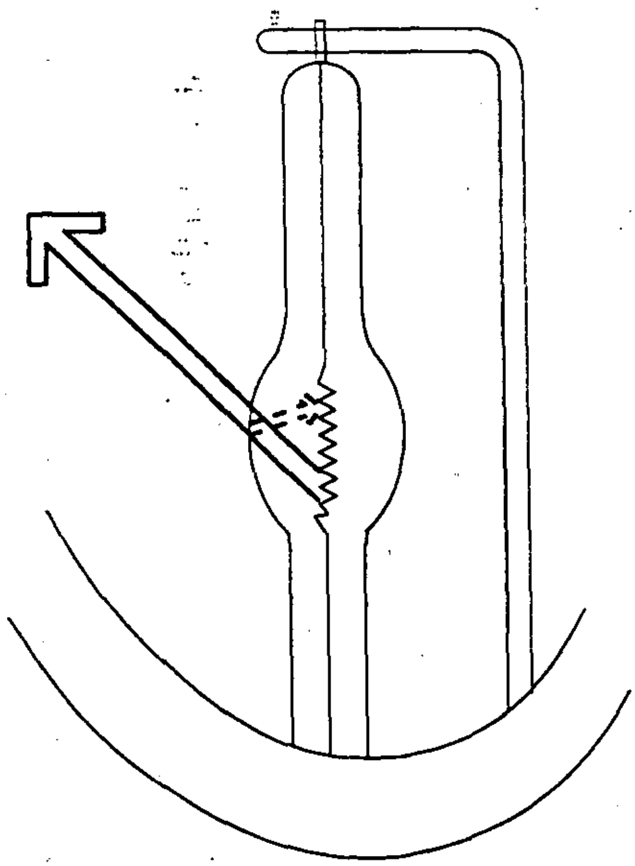

Figure 7-5

Dichroic film transmits visible light while reflecting infrared radiation (dotted line) back to the filament.

Efficacy and Efficiency

Even though halogen lamps are generally more energy-efficient than standard incandescent lamps, they are only moderately efficacious. Most standard capsule halogen lamps have an efficacy of around 20 lumens per watt, while the efficacy of infrared-reflecting halogen lamps can exceed 30 lumens per watt. By comparison, the efficacy of a

Figure 7-6

Double-Ended Infrared Reflecting Halogen Lamps

Lamp Designation	Watts	Rated Lamp Life (Hours)	Initial Lamp Lumens	Lumens Per Watt
Q500T3/350	350	2000	10,000	29
Q1500T3/900	900	2000	32,000	36

Notes:
Lamps require proper luminaires equipped with safety shields.
See Figures 7-11 for PAR halogen infrared reflecting lamps.

standard 1750 lumen, 100-watt A lamp is only 17.5 lumens per watt.

Nevertheless, while tungsten-halogen lamps are not particularly efficacious in terms of lumens per watt, the small filament of halogen lamps allows for extremely efficient optical systems and reflectors to be utilized. The result is potentially greater candlepower per watt than most other accent lighting or display lighting sources.

Color Temperature and Rendition

The halogen capsule lamps offer extremely attractive light at about 3000 K. This color temperature appears significantly "whiter" than other incandescent light sources. The color rendering index (CRI) is approximately 100. When dimmed, the color temperature falls, as holds true with other incandescent lamps. Lamps with infrared-reflecting films generally have the same color characteristics, but a film's absorption may be varied to create slightly different color temperatures or tints.

Figure 7-7 compares the color temperature of tungsten-halogen lamps with other light sources.

Lamp Life

Lamp life in tungsten-halogen lamps generally ranges from 2000 to 3500 hours. However, in PAR envelopes, lamps may last up to 6000 hours. In addition, lamp life can be extended by dimming, although the increased lamp life does not follow standard incandescent lamp curves, so manufacturers' data will need to be consulted. Periodic high power operation may be required to raise a lamp's temperature up to the level needed to activate the halogen cycle. Continuous dimming below 35% is not recommended.

Diodes

There is a controversy within the lighting industry between manufacturers who use series diodes in the design of tungsten-halogen lamps, and those who do not. Over the next two years, diodes will probably be phased out of all tungsten-halogen lamps, except for PAR-16 lamps, due to performance irregularities and competitive pressures.

Some PAR halogen lamps designed to operate from a line voltage of 120 volts incorporate a diode in series with the lamp filament. The object of the diode is to reduce lamp filament voltage to about 84 volts. This allows for increased filament thickness and decreased filament area, resulting in a smaller filament and greater optical control over distribution of the light.

Diodes reduce voltage through half wave rectification of the 60 Hz input supply voltage. This means that the diode, in effect, "eliminates" half of the sinusoidal wave form. This increases lamp flicker above the usual 5% flicker characteristic of incandescent lamps. Dimming of these lamps

Figure 7-7

Tungsten-Halogen Lamp Color Comparison Chart

Light Source	Color Temperature (K)	In Comparison, Tungsten-Halogen Lamps Appear
Standard Incandescent	2800 K	Slightly Cooler and Whiter
Standard Quartz	3000 K	Same
Low-Voltage Quartz (MR-16)	3100 K	Slightly Warmer
Warm White Fluorescent	3000 K	Slightly Warmer
Cool White Fluorescent	4100 K	Warmer and Redder
Rare Earth Phosphor Fluorescent	2700 K	Slightly Warmer
	3000 K	Same
	3500 K	Slightly Warmer
	4100 K	Warmer
Metal Halide	3100 K	Slightly Redder
	4100 K	Much Warmer & Redder
Standard HPS	2200 K	Much Whiter & Bluer
White HPS	2600 K	Whiter

increases flicker further, often to a level that is objectionable.

Diodes block either the positive or negative cycles of the input voltage. As such, a single lamp will have a low power factor and high harmonics compared to a regular incandescent lamp. If diode lamps of the same polarity (positive or negative) make up a significant portion of the branch circuit power, power quality, and dimming capabilities may be adversely affected. However, if the diode polarities are randomly altered, so that half the diodes block the positive cycle of input voltage and the other half block the negative cycle, the power quality, and dimming capabilities are indistinguishable from incandescent lamps with no diodes. It would be helpful if manufacturers of diode lamps could somehow label those lamps so that the polarity of the diodes is recognizable. It is important that lighting maintenance staff be aware of the polarity requirements of this product when relamping. In any case, individual or small numbers of lamps should be dimmed with diode-rated dimmers only.

From a power quality standpoint, individual diode lamps have 100% current harmonic distortion. There is no distortion, however, if an equal wattage lamp with a diode of opposite polarity is added to the circuit.

Other Applicable Technologies

Halogen lamps are relatively low efficacy sources, so their use should be restricted to applications where the unique characteristics of these lamps are needed. A common misapplication with halogen lamps is the general lighting of large spaces with tungsten-halogen sources. Ideally, halogen should be used only in applications in which high levels of footcandles are only needed in small areas. Otherwise, designers should investigate other more energy-efficient options. For illumination of larger areas, consider one of the following:

- Compact metal halide and white high pressure sodium lamps in general lighting, wall washing, and display lighting situations
- Compact fluorescent lamps, especially in area lighting and wall washing situations
- High-wattage, high intensity discharge (HID) lamps for industrial and commercial situations where a high lumen, high efficacy source is needed

Limitations

In general, tungsten-halogen lamps are more efficacious than incandescent lamps, but they have some limitations when applied to architectural lighting. These include:

- Some lamp sockets and bases are unusual and, due to compact size and high heat, are prone to failures unless of good quality.
- Quartz envelopes must not be handled with bare hands.
- Lamps must be protected by a cover glass or have an integral glass envelope, to prevent damage from possible lamp rupture, and to protect against excess UV radiation.

Overall, tungsten-halogen lamps are somewhat more energy efficient than standard incandescent lamp sources. Nevertheless, it should be noted that, except for the specific lamp types discussed in the following section, most tungsten-halogen lamps (*except* for those used in theater and entertainment lighting) probably have a more energy-efficient alternative.

Current Products

Low-Voltage Tungsten-Halogen Lamps

Low-voltage tungsten-halogen technology derived from systems already in use in automotive and aircraft applications. Tungsten-halogen technology allows for an extremely compact lamp envelope and filament, making the source ideal for sealed-beam and replaceable lamp headlights.

Most low voltage halogen lamps use a compact quartz-glass envelope or "bud" with two vertical pin terminals. A few products employ bayonet or double contact bayonet bases, such as those used in flashlights and aircraft, or glass wedge bases. Bare "bud" lamps are designed for use in a variety of special purpose luminaires, and many different wattages are available.

The most common applications for low-voltage halogen lamps are as projector or reflector lamps. In these lamps the halogen bud is backed with a reflector of aluminum or glass. There are three distinct types of projector lamps: multi-mirror reflector (MR) lamps; aluminum reflector (AR) lamps; and low-voltage PAR-36 lamps. These lamps are described in terms of appearance and performance characteristics in the following pages.

Figure 7-8
MR-16 Lamp

MR Lamps

MR lamps have dichroic-coated faceted glass reflectors, and they are available in many wattages and beam spreads for a variety of accent lighting applications.

The most popular low-voltage lamps are MR-16 bipin projector lamps. MR-16 lamps were originally developed as slide projector lamps, using forced-air cooling and 82 to-120-volt, 200-300-watt lamps. The architectural versions are 20-75-watt, 12-volt lamps. The reflector is made of faceted glass, coated with a dichroic film that reflects visible light and transmits infrared energy through the back of the lamp, making the MR-16 beam inherently a "cool beam" lamp. The reflector is the ellipsoidal type, making the MR-16 lamp especially good for framing and effects projectors. MR-11 lamps are smaller and generally of lower wattage, but offer similar performance.

The MR-16 lamp is made in very narrow spot, narrow spot, narrow flood, and wide flood beam spreads. Beam spreads are determined by the size and orientation of the facets on the lamp's reflector face. MR-16 lamps are available in standard wattages of 20, 35, 42, 50, 65, and 75. Additionally, there are a number of special MR-16 products, some of which are described below.

- Cover glass lamps are suitable for open lamp applications, such as open wire systems (note: tungsten-halogen luminaires must have a cover glass protector over the lamp to receive UL listing).
- Lamps with aluminum reflector coatings prevent lamp back glow, but eliminate the cool beam effect.
- Lamps with improved dichroic coatings provide constant color over lamp life, longer lamp life, and improved lumen maintenance.
- Lamps with color dichroic coatings (red, yellow, green, and blue) are used for special lighting effects..
- Square-shaped, MR lamps have been designed to provide similar candlepower as higher wattage round MR products.

Performance characteristics of MR-16 lamps are shown in Figure 7-9. MR lamps are also available in a smaller MR-11 (37 mm) configuration. As shown in Figure 7-10, MR-11 lamps are generally offered in 12, 20, 35, and 50-watt versions, with a similar choice of beam spreads. Unlike MR-16 lamps, however, some manufacturers make MR-11 lamps with double contact bayonet bases. The thin pins of the standard MR-11 bipin lamp are not as strong as the MR-16's, and some luminaire manufacturers recommend the double contact bayonet base lamp for durability and added corrosion resistance.

Figure 7-9

MR-16 Tungsten-Halogen Lamps

Proposed ANSI C78.1 Lamp Designation	Lamp Watts	Lamp Life	Beam Spread	Center Beam Peak Candlepower	Notes
MR-16 Lamps: Dichroic-coated multi-mirrored reflector, 51 mm (2") diameter, 12-volt operation, GX5.3 bipin base, no filament shield, "CG" = Cover Glass Option					
20MR16/7°	20	3000	VNSP 7 DEG	8200	
20MR16/13°	20	3000[1]	NSP 13 DEG	3350	CG
20MR16/25°	20	3000	NFL 23 DEG	950	CG, 880 CP
20MR16/40°	20	4000	FL 40 DEG	525	CG, 490 CP
30MR16/6°	30	2000	VNSP 6 DEG	8500	
35MR16/12°	35	4000	NSP 12 DEG	7900	CG, 7600 CP
35MR16/25°	35	4000	NFL 23 DEG	2500	CG, 2300 CP
35MR16/40°	35	4000	FL 40 DEG	1200	CG, 1100 CP
42MR16/9°	42	3500	VNSP 9 DEG	13,100	
42MR16/25°	42	3500	NFL 27 DEG	2100	
50MR16/15°	50	4000[2]	SP 14 DEG	10200	CG, 9500 CP
50MR16/25°	50	4000[2]	NFL 27 DEG	2900	CG, 2700 CP
50MR16/30°	50	4000[2]	NFL 32 DEG	2325	CG, 2250 CP
50MR16/40°	50	4000[2]	FL 40 DEG	1725	CG, 1500 CP
50MR16/55°	50	4000[2]	WFL 55 DEG	1150	
65MR16/15°	65	3500	SP 14 DEG	11500	CG OPTION
65MR16/25°	65	3500	NFL 23 DEG	4000	CG OPTION
65MR16/40°	65	3500	FL 38 DEG	2000	CG OPTION
75MR16/15°	75	4000	SP 14 DEG	12,300	CG, 12,300 CP
75MR16/25°	75	4000	NFL 24 DEG	4600	CG, 4600 CP
75MR16/40°	75	4000	FL 42 DEG	2100	CG, 2100 CP

Notes:
(1) Lamp life increases to 4000 hours for lamps with improved constant color dichroic coatings.
(2) Lamp life increases to 5000 hours for lamps with improved constant color dichroic coatings.

Square MR-16 Lamps Dichroic-coated multi-mirrored reflector, 51 mm (2") diameter, 12-volt operation, GX5.3 bipin base, no filament shield; candlepowers are average center beam.

	Lamp Watts	Lamp Life	Beam Spread	Center Beam Peak Candlepower	
	20	3000	SP 12 DEG	4500	
	20	3000	FL 36 DEG	700	
	39	3000	SP 12 DEG	9150	
	39	3000	NFL 24 DEG	3000	
	39	3000	FL 38 DEG	1500	
	49	3500	SP 12 DEG	11,500	
	49	3500	NFL 24 DEG	4800	
	49	3500	FL 38 DEG	2000	

Figure 7-10
MR-11 Tungsten-Halogen Lamps

Proposed ANSI C78.1 Lamp Designation	Lamp Watts	Lamp Life	Beam Spread	Center Beam Peak Candlepower	Notes
12MR11/8°	12	3000	NSP 8 DEG	1500	6 VOLT
20MR11/10°	20	3000	NSP 10 DEG	3900	
20MR11/15°	20	3000	SP 17 DEG	1550	
20MR11/30°	20	3000	NFL 30 DEG	600	
35MR11/10°	35	3000	NSP 10 DEG	5850	
35MR11/20°	35	3000	SP 20 DEG	2750	
35MR11/30°	35	3000	NFL 30 DEG	1300	

Notes:
Lamp designations are subject to change.
Except where noted, lamps are 12-volt operation.
Lamps with G-4 bipin bases are listed; optional DC bayonet base also available from some manufacturers.

AR Low Voltage Lamps

Aluminum reflector "AR" lamps with or without integral glass lens are available in configurations ranging from AR-40 (R-12 size) up to AR-111 (PAR-36 size). Some designers prefer using AR lamps over MRs due to their more consistent color characteristics. AR lamps are readily available in Europe, but are often difficult to find in the United States.

Performance characteristics of AR lamps are described in Figure 7-12.

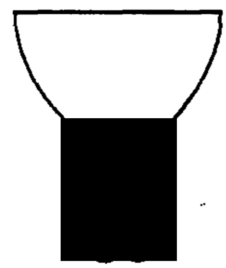

Figure 7-11
AR Type Lamp

Figure 7-12
Performance Characteristics of AR Type Tungsten-Halogen Lamps

Proposed ANSI C78.1 Lamp Designation	Lamp Watts	Lamp Life	[redacted]	Peak Candlepower	Notes
AR-37 Lamps: Aluminum reflector, 37 mm diameter, 6 or 12-volt lamps, double contact bayonet base, no filament shield, integral cover glass..					
15AR37/6°	15	3000	NSP 6 DEG	5000	6 VOLT
20AR37/6°	20	3000	NSP 6 DEG	7000	
20AR37/20°	20	3000	SP 18 DEG	1400	
20AR37/30°	20	3000	FL 32 DEG	350	

Figure 7-12 (continued)

Performance Characteristics of AR Type Tungsten-Halogen Lamps

AR-48 Lamps, Aluminum reflector, 48 mm diameter, 12 or 24-volt lamps, G-4 bipin base, filament shield, no cover glass, optional 3100K silver color or 2600K gold color reflector, as noted.					
20AR48/10°	20	2000	NSP 10 DEG	5000	
20AR48/15°	20	2000	SP 15 DEG	2000	
20AR48/10°	20	2000	NSP 10 DEG	4500	GOLD REFL.
20AR48/15°	20	2000	SP 15 DEG	1500	GOLD REFL.
20AR48/10°	20	2000	NSP 10 DEG	4500	24 VOLT
AR-58 Lamps: Aluminum reflector, 56-58 mm diameter, 6 or 12-volt lamps, double contact bayonet base. no filament shield, integral cover glass.					
15AR58/4°	15	2000	VNSP 4 DEG	12,000	6 VOLT
15AR58/15°	15	2000	NFL 14 DEG	1400	6 VOLT
35AR58/6°	35	2000	VNSP 6 DEG	15,500	6 VOLT
35AR58/15°	35	2000	NFL 14 DEG	4000	6 VOLT
15AR58/8°	50	2000	NSP 8 DEG	11,000	
50AR58/15°	50	2000	NFL 16 DEG	4650	
50AR58/25°	50	2000	FL 25 DEG	1900	
50AR58/30°	50	2000	FL 32 DEG	1100	
AR-70 Lamps: Aluminum Reflector, 70 mm diameter, 12-volt lamps, double contact bayonet base, filament shield, no cover glass, 3100K silver color or 2600K gold color reflector, as noted.					
20AR70/10°	20	2000	SP 10 DEG	7000	
20AR70/30°	20	2000	FL 30 DEG	1000	
50AR70/10°	50	2000	SP 10 DEG	15,000	
50AR70/30°	50	2000	FL 30 DEG	2000	
50AR70/10°	50	2000	SP 10 DEG	13,500	GOLD REFL.
50AR70/30°	50	2000	FL 30 DEG	1800	GOLD REFL.
75AR70/10°	75	2000	SP 10 DEG	19,000	
75AR70/30°	75	2000	FL 30 DEG	4000	
AR 111 Lamps: Aluminum reflector, 111 mm diameter, 12-volt lamps, screw and lug terminals, filament shield, no cover glass. In some cases, may be interchangeable with PAR-36 lamps.					
35AR111/3°	35	2000	VNSP 3 DEG	45,000	6 VOLT
50AR111/5°	50	2000	NSP 5 DEG	50,000	
50AR111/10°	50	2000	SP 10 DEG	20,000	
50AR111/30°	50	2000	FL 30 DEG	3000	
75AR111/10°	75	2000	SP 10 DEG	25,000	
75AR111/30°	75	2000	FL 30 DEG	4500	
75AR111/60°	75	2000	WFL 60 DEG	1300	
100AR111/10°	100	2000	SP 10 DEG	45,000	
100AR111/30°	100	2000	FL 30 DEG	7000	
100AR111/60°	100	2000	WFL 60 DEG	2000	

Note: Lamp designations are subject to change

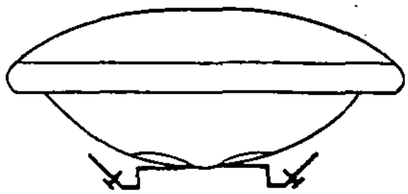

Figure 7-13
Par 36 Lamp

PAR-36 Lamps

Low-voltage PAR-36 lamps have been popular with lighting designers for many years. Halogen buds within PAR-36 glass envelopes provide similar performance to standard incandescent PAR-36 lamps but with improved color rendering, longer lamp life, and improved energy efficiency. In addition, low-voltage PAR-36 lamps provide exceptional beam spread control.

Figure 7-14 lists performance characteristics of low-voltage PAR-36 lamps.

Figure 7-14
PAR-36 Halogen Low-Voltage Lamps

Proposed ANSI C78.1 Lamp Designation2	Lamp Watts	Lamp Life	Beam Spread	Peak Center Candlepower	Notes
Halogen PAR-36 Lamps: Aluminized glass reflector, sealed beam glass cover, 4-1/2" diameter, 12-volt lamps, filament shield, internal halogen "bud" element, screw and lug terminal					
35PAR36/5°	35	4,000	VNSP 5 DEG	25,000	
35PAR36/8°	35	4,000	NSP 8 DEG	8,000	
35PAR36/30°	35	4,000	WFL 30 DEG¹	900	
50PAR36/5°	50	4,000	VNSP 5 DEG	40,000	Open Reflector
50PAR36/8°	50	4,000	NSP 8 DEG	11,000	Open Reflector
50PAR36/30°	50	4,000	WFL 30 DEG¹	13,000	Open Reflector

Notes:
1. Beam spreads for WFL lamps measure approximately 35 DEG X 25 DEG
2. Lamp designations are subject to change

Limitations of Low-Voltage Lamps

Halogen low-voltage reflector lamps have been responsible for considerable excitement in the lighting industry. However, there has been a great deal of misinformation and misrepresentation about the advantages of low-voltage lighting.

The actual advantages of low-voltage lighting include:

- Mostly very compact lamps
- Low-wattage lamps that are nevertheless able to create an intense, focused beam
- Traditional halogen color temperature and lamp life advantages
- Higher efficacy than most equivalent line-voltage incandescent lamps

The disadvantages of low-voltage halogen lamps, however, are seldom mentioned; they include:

- Low-voltage halogen lamps have low efficacy in comparison with most other advanced lighting technologies. Efficacy of these lamps is generally under 20 lumens per watt, which, like with most other incandescent lamps, makes them a poor source for general lighting applications.
- Low-voltage halogen lamps require a transformer to develop the low-voltage (usually 12 volts) for the lamp. This requirement may cause size, noise, cost, and potential dimming problems.
- Low-voltage halogen lamps are often expensive and lamp quality may be unreliable, especially from off brand MR lamps.

Halogen Capsule Lamps

To expand the applications of tungsten-halogen lamps, products were developed with a small tungsten-halogen capsule lamp within a standard lamp shape such as the PAR lamps shown in Figure 7-15. These lamps operate at 120 volts and most have common medium screw-in bases (a few side prong lamps are also available). Some manufacturers place a diode within the lamp assembly and operate the filament at the equivalent of 84 volts half-wave rectified (see earlier discussion on diodes).

This family of products has expanded the range of applications for tungsten-halogen lamps. Most of the halogen capsule lamps now available are reasonably priced, low-wattage alternatives to the standard incandescent lamps they are designed to replace. Virtually all of these lamps can be used in standard luminaire designs, as long as the lamp wattage does not exceed the luminaire rating.

There are two principal variations to the halogen capsule type of lamp: common lamp shapes designed to replace standard incandescent lamps; and PAR lamps in several configurations.

Common Lamp Shapes

Several varieties of capsule lamps are available in common shapes. Notable configurations include an A-lamp shape and a series of tubular (T) shaped lamps. These lamps are used primarily as retrofits for existing standard incandescent luminaires. Capsule lamps have much longer lamp life (up to 3500 hours) and use about 30% less electricity to generate about the same light output as the lamps they replace.

Halogen PAR Lamps

Halogen PAR capsule lamps, such as those illustrated in Figure 7-15, include both the traditional PAR-38 and newer, smaller PAR-30, PAR-20, and PAR-16 envelopes. They are useful in many new construction lighting applications, and they are valuable replacements for inefficient R and standard PAR lamps. Notable variations include the following.

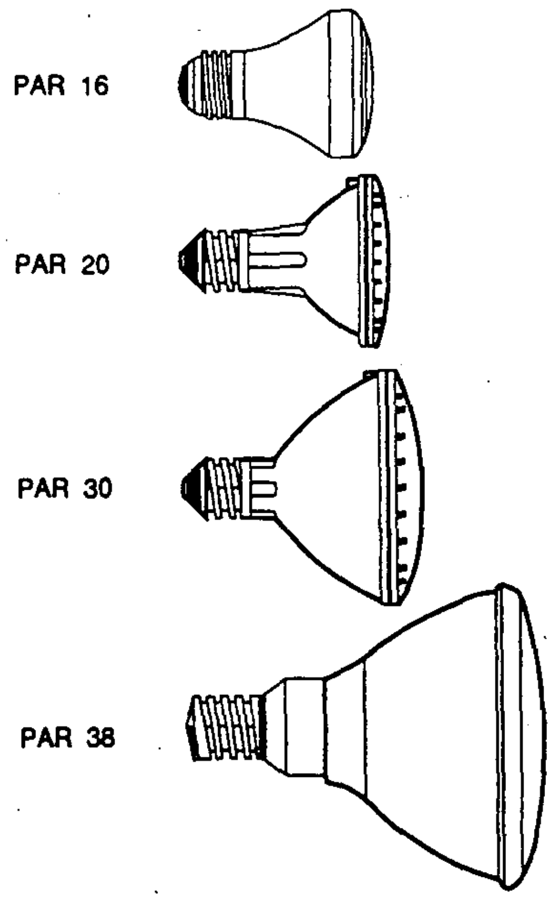

Figure 7-15
Halogen PAR Lamps

- Long neck PAR-20 and PAR-30 lamps are designed to be used in existing luminaires that were originally designed for R-lamps.
- "Cool beam" PAR lamps have dichroic reflectors similar to those supplied with MR-16 lamps. These lamps reduce heat on lighted objects by transmitting infrared radiation away from the object being illuminated.
- IR reflecting PAR lamps use the reflecting IR film to increase light output and efficacy.

Figures 7-16 and 7-17 list the performance characteristics of halogen PAR lamps.

Figure 7-16

Halogen PAR30 and PAR 38 Lamps

Proposed ANSI C78.1 Lamp Designation1	Watts	Lamp Life	Beam Spread	Center Beam Candle-power2	Notes
			PAR-30 Halogen Lamps		
50HPAR30/11°	50	2000	11 DEG	10,500	
50HPAR30/24°	50	2000	24 DEG	2700	Cool Beam Option
50HPAR30/35°	50	2000	36 DEG	1600	
50HPAR30/7°	50	2000	7 DEG	19,500	IR-Reflecting
50HPAR30/25°	50	2000	23 DEG	4000	IR-Reflecting
50HPAR30/35°	50	2000	33 DEG	2600	IR-Reflecting
50HPAR30/9°	50	2000	9 DEG	9900[3]	Long Neck
50HPAR30/15°	50	2000	16 DEG	4200[3]	Long Neck
50HPAR30/30°	50	2000	30 DEG	1900[3]	Long Neck
50HPAR30/40°	50	2000	40 DEG	1250[3]	Long Neck
75HPAR30/11°	75	2000	11 DEG	15,000	
75HPAR30/25°	75	2000	24 DEG	6000	Cool Beam Option
75HPAR30/35°	75	2000	36 DEG	2500	
			PAR-38 Halogen Lamps		
45HPAR/10°	45	2000	10 DEG	9300	
45HPAR/12°	45	2000	12 DEG	6900	
45HPAR/32°	45	2000	32 DEG	1700	
60HPAR/12°	60	3000	12 DEG	15,000	IR-Reflecting
60HPAR/30°	60	3000	32 DEG	3300	IR-Reflecting
60HPAR/55°	60	3000	53 DEG	1250	IR-Reflecting
75HPAR/10°	75	2500	10 DEG	17,500	
75HPAR/30°	75	2500	30 DEG	3,500	
90HPAR/10°	90	2000	10 DEG	19,000	
90HPAR/12°	90	2000	12 DEG	16,000	Cool Beam Option
90HPAR/30°	90	2000	30 DEG	3500	Cool Beam Option
90HPAR/55°	90	2000	55 DEG	2500	
100HPAR/10°	100	3000	10 DEG	28,000	IR-Reflecting
100HPAR/35°	100	3000	33 DEG	5500	IR-Reflecting
150HPAR/9°	150	3000	9 DEG	37,500	
150HPAR/10°	150	4000	10 DEG	29,000	
150HPAR/20°	150	4000	22 DEG	7200	
250HPAR/10°	250	6000	10 DEG	52,000	
250HPAR/20°	250	6000	22 DEG	12,000	

Notes:
Lamp designations are subject to change.
Values listed are typical for most manufacturers; however some variance is to be expected between manufacturers.
Candlepower values for long neck lamps are average center beam; all others are peak center beam.
Side prong 90HPAR/3 now available in some beam spreads.

Figure 7-17

Halogen PAR16 and PAR 20 Lamps

Proposed ANSI C78.1 Lamp Designation[1]	Watts	Lamp Life	Beam Spread	Center Beam Candle-power[2]	Notes
PAR-16 Halogen Lamps: Diode equipped with ceramic-backed reflector					
40PAR16/10°	40	2000	10 DEG	5000	
40PAR16/25°	40	2000	27 DEG	1300	
55HPAR16/12°	55	2000	12 DEG	5000	
55HPAR16/30°	55	2000	30 DEG	1300	
60HPAR16/10°	60	2000	10 DEG	7500	
60HPAR16/25°	60	2000	27 DEG	2000	
75HPAR16/12°	75	2000	12 DEG	7500	
75HPAR16/30°	75	2000	30 DEG	2000	
PAR-20 Halogen Lamps					
50HPAR20/10°	50	2000	10 DEG	6000	
50HPAR20/25°	50	2000	26 DEG	1850	Cool Beam Option
50HPAR20/9°	50	2000	9 DEG	6200[3]	Long Neck
50HPAR20/15°	50	2000	16 DEG	3200[3]	Long Neck
50HPAR20/30°	50	2000	30 DEG	1400[3]	Long Neck

Notes:
Lamp designations are subject to change.
Values listed are typical for most manufacturers; however some variance is to be expected between manufacturers.
Candlepower values for long neck lamps are average center beam; all others are peak center beam.

Application Guidelines

Halogen low-voltage lamps are an important and extremely popular specialty light source. Applications ranging from recessed "pin spots" to cove lighting strips make use of these low wattage white color sources. Low-voltage projector type lamps, such as MR-11s and MR-16s are an excellent display light source for art, jewelry, and other *precision* lighting situations. However, like regular tungsten-halogen lamps, low-voltage halogen lighting is often used when a more energy-efficient source, such as standard voltage halogen infrared-reflecting lamps or compact fluorescent lamps, may be a better choice. This is particularly true for general area lighting applications.

Halogen capsule lamps, infrared-reflecting film coated lamps, and low-voltage projector lamps have a broad range of applications. In new designs, the PAR and low-voltage MR lamps are excellent products for retail lighting and other forms of small area display and accent lighting. In retrofit situations, many PAR and IR-reflecting halogen lamps can be used for direct, immediate replacement of more traditional/less energy-efficient technologies, in everything from recessed downlights and wall sconces, to power floodlights and chandeliers.

Although many tungsten-halogen lamps are manufactured in typical incandescent lamp shapes, some are not suitable for unprotected exterior locations unless they are in enclosed luminaires.

In general, halogen capsule and infrared-reflecting film lamps are best applied in one of the following ways:

- *Cost-Effective and Efficient Display Lighting* The capsule PAR, infrared-reflecting film PAR, and low-voltage lamps all make excellent display sources for retail lighting installations, especially where tight control of beam spread is necessary.
- *Energy-Efficient Lamps in Conventional Luminaires* If design requirements preclude the use of more efficient technologies (such as fluorescent lamps and ballasts), consider halogen lamps in traditional luminaires such as downlights. This is most often justified when full-range dimming is required. Additionally, halogen PAR and PAR-IR lamps make excellent, inexpensive, and simple-to install retrofit solutions for luminaires that use standard reflector and PAR lamps.

Most tungsten-halogen lamps can be dimmed with conventional incandescent dimmers, although dimming can reduce the effectiveness of the halogen cycle. Continuous dimming below 35% may reduce lamp life and/or increase lumen depreciation. Series diode lamps may experience some dimming anomalies, such as increased flicker, but non-diode lamps will operate extremely well on most dimmers.

Residential Applications

Tungsten-halogen lamps make excellent light sources for many residential applications, including virtually every incandescent luminaire for which a suitable lamp style exists. In some instances, halogen lamps can replace standard incandescent with a significant reduction in wattage. For example, 90-watt halogen PAR lamps make excellent replacements for 150-watt R-40 lamps in recessed downlight luminaires. The flicker of halogen lamps with diodes may be most noticeable in these situations, so caution is urged.

Since halogen PAR and low-voltage lamps are display lamps, they can be used for residential accent situations, such as lighting artwork or accenting architectural and landscaping features.

Commercial Applications

The advent of the halogen PAR-IR lamp began a new era in retail display lighting. Situations traditionally lighted with 150-watt PAR lamps could be lighted with 60-watt PAR-IR lamps with no degradation of lighting quality. Replacement of traditional incandescent PAR lamps with halogen IR-reflecting technologies can be achieved without any need to change luminaires; the lamps simply screw into existing medium base sockets.

In some commercial situations, the halogen and halogen film lamps are the best choice only when fluorescent and HID options have been eliminated. Typical situations generally involve dimming where only incandescent and halogen sources can provide truly effective full-range dimming effects at reasonable expense.

In luminaires that use standard halogen lamps, direct replacement of the ordinary tungsten-halogen lamp with an infrared-reflecting film lamp provides a substantial savings. Even though the options are presently quite limited, several of the most common tungsten-halogen lamps (Q300T3, Q500T3, and Q1500T6) can be directly replaced with a savings of 30% to 40%.

Examples

Retail Display Lighting

Many stores use track lighting for retail display. The traditional light source has been PAR-38 lamps in 150-watt or 120-watt "energy-saving" sizes. However, by substituting more efficient standard halogen capsule lamps, suitable 60, 75, and 90-watt lamps may be used which will provide similar performance.

Savings potential is significant. The per unit reductions are from 60 to 90 watts per socket, or 40% to 60%, without any significant change in performance. Since in many stores the only lighting system is the track, this correlates to a direct energy savings of 40% to 60% for most of the property. The added cost of even the most expensive lamps, presently about $5.00, is amortized in one-third to one-half the normal life of the lamp for typical power costs.

Power Floodlighting

A common fixture design utilizes a double-ended 500-watt quartz lamp. Although an HID light source would be far more energy efficient, many applications call for an instant-on lamp. Specifying the infrared-reflecting film version of the double ended lamp results in virtually the same amount of light with a 350-watt lamp.

Savings potential is significant. Over the life of the lamp, more than 300 kilowatt hours are saved, which easily pays for the lamp cost premium several times over.

Guideline Specifications

In order to specify halogen capsule lamps, it is important to determine whether diode lamps are acceptable for the installation. Should the specifier have any concern over diodes, it is probably appropriate to write a proprietary specification designating the acceptable vendors.

Second, since halogen projector lamps are available in a variety of beam spreads, the specifier should be exacting in his or her selection. There is a distinct possibility of different beam spreads from different manufacturers, so caution is again urged in selecting between a generic specification and a proprietary specification.

Third, the market-driven lamp product development has made standardization of halogen lamp nomenclature difficult. At the time of this printing, the ANSI C78-1 committee was attempting to finalize nomenclature standards for many tungsten-halogen lamps. For instance, it has been proposed that the three-letter photographic code (BAB, EXZ, etc.) be eliminated for MR-16 lamp designations. Similarly, another proposed measure would categorize all reflector lamp beam spreads in degrees to replace the current lettering (FL, NSP, etc.). However, adoption of these standards is still pending. As such, while these guidelines should allow for reasonable accuracy, specifiers are urged to use manufacturer's advertised nomenclature and trade names if the differences in products are significant.

Finally, the specifier is reminded that the descriptions "halogen" and "quartz" do not necessarily refer to the same product, and they should therefore not be used interchangeably. Many of the capsule lamps do not use quartz glass (which keeps the cost down). Therefore, although most quartz lamps are tungsten-halogen lamps, not all tungsten-halogen lamps are quartz lamps.

Lamp Designations

The lamp designation can be specified as follows:

(Quartz)/Wattage/Shape/(Beam-spread)/(Manufacturer's Designation)

Specification Examples

- A 90-watt halogen capsule PAR-38 narrow spot (9°) would be: 90PAR38NSP/H or 90PAR38NSP/CAP. Under the proposed ANSI standard, the specification would change to: 90HPAR/9°.
- A 50-watt MR-16 lamp with a narrow flood (25°) beam spread (EXZ) would be as follows: 50MR16NFL, or 50MR16EXZ. Under the proposed ANSI standards, the specification would be: 50MR16/25°.

Manufacturer/Product References

Manufacturer	Products
Duro-Test	Halogen lamps
General Electric	Halogen lamps, Infrared-reflecting halogen lamps Constant color MR lamps
Iwasaki	Halogen lamps
OSRAM	Halogen lamps
Panasonic	Halogen lamps Infrared-reflecting halogen amps
Philips	Halogen lamps Long neck halogen PAR lamps Square MR-16 lamps
Sylvania	Halogen lamps

(Inclusion in this list does not imply applicability or endorsement by the California Energy Commission, The U.S. Department of Energy, or the Electric Power Research Institute. Additional companies may also manufacture these products.)

Metal Halide and HPS Lamps

California Energy Commission
Building and Appliance Efficiency Office

Technology Description

Metal halide and high pressure sodium (HPS) lamps are the preferred modern lamps of the family known as high intensity discharge (HID). (Mercury vapor lamps, another type of HID, are not as efficient and therefore not reported in this guideline.) Like fluorescent lamps, HID lamps require ballasts to provide proper starting and operating voltages, and they produce light through the discharge of an electric arc through a mixture of gases. HID lamps all utilize a compact "arc tube" in which very high temperature and pressure exist. This small arc tube closely resembles a point source of light, making HID lamps and their luminaires both compact and powerful.

Ballasts and Starters

HID lamps require ballasts to regulate the arc current flow and to deliver the proper voltage to the arc. Larger ("standard") metal halide lamps employ a starting electrode within the lamp to initiate the arc (see Figure 8-1). Smaller metal halide and HPS lamps, on the other hand, do not contain starting electrodes. Instead, the lamp is started by a high voltage pulse to the operating electrodes. An electronic starting circuit associated with the ballast generates this pulse. American National Standards Institute (ANSI) lamp-ballast system standards establish parameters for all HID components, except for newly introduced products.

A few electronic ballasts are now available for HID lamps.

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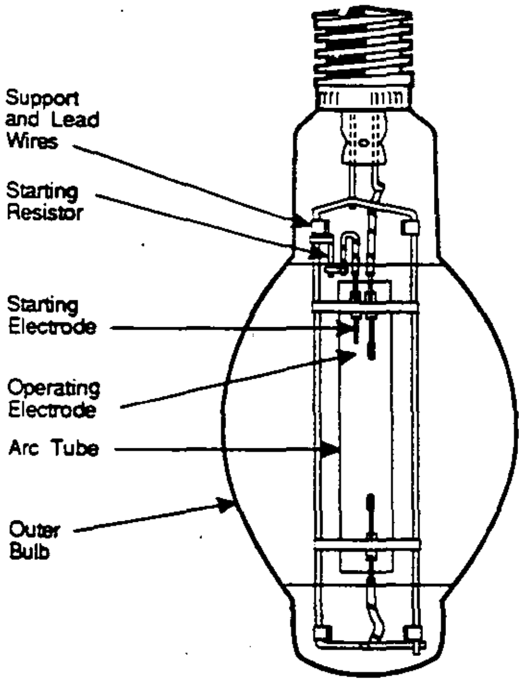
Electronic ballasts for HID lamps do not use the same principles as for fluorescent lamps – the primary benefit of an electronic HID ballast is more precise management of the lamp's arc tube wattage over life. By better managing the arc tube wattage, more consistent color and longer lamp life usually occur. With few exceptions, high frequency operation does not increase HID lamp efficacy.

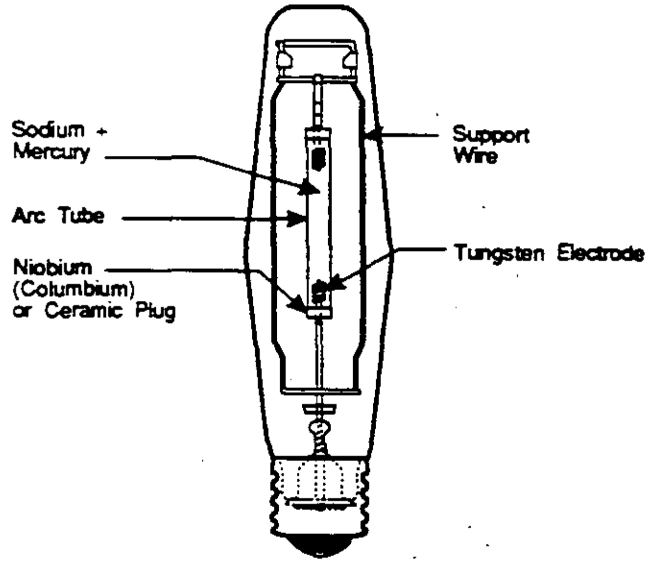
Striking and Warm-Up

It is not possible to instantly ignite a cold HID lamp to full brilliance. All HID lamps employ a mixture of gases and metals in the arc tube. As power is applied, temperature and pressure build gradually, causing vapors of the metals to enter into the arc and release light energy. The starting of the arc sometimes takes a few seconds, and the duration of the warm-up period varies depending on lamp type, ranging from 2 to 10 minutes. During this period, the lamp will exhibit different colors as the various metals vaporize.

Lamp Restrike

If power is interrupted, even briefly, an HID lamp's arc will extinguish. The lamp must then cool down before the arc can





Metal Halide Lamp

High Pressure Sodium Lamp

Figure 8-1
Metal Halide and High Pressure Sodium Lamp Construction

restrike. Lamp restrike periods vary, depending on lamp type, and can last from 1 to 15 minutes. Restrike time is a major concern in applications where a prolonged lighting interruption could create hazardous conditions or a manufacturing shutdown. A few metal halide products are made with "instant restrike" capability, requiring special outboard electronics to generate extremely high voltages which overcome the elevated lamp temperature and pressure and regenerate the arc. In addition, some HPS lamps are available that will restrike immediately to approximately 10% of full light output. These lamps contain 2 arc tubes and will reach full light output in approximately 90 seconds. Alternatively, HID luminaires are available that contain supplementary high output quartz backup lamps. In the event of a brief power interruption the backup lamps ignite until the HID lamp's arc can restrike. The relative infrequency of power interruptions, as well as increased cost, make the use of instant restrike products relatively uncommon.

Dimming

It is possible to dim some HID lamps. Dimming requires specialized ballasts and dimming electronics, and operating HID lamps at less than full output will produce color shift and reduced lamp efficacy. For example, a metal halide lamp can be dimmed to about 40% power, but at this level it generates only about 25% of its rated lumens, and it will change color in an undesirable manner.

Energy Efficiency

HID lamps are among the most energy-efficient lamp technologies available. White sodium lamps have the lowest efficacy of the HID sources, producing between 40 and 50 lumens per watt. Metal halide lamps range from 55 (70-watt open fixture lamp) to 110 lumens per watt for a 1000-watt horizontal high output lamp. The most efficacious white light HID sources are standard high pressure sodium lamps, ranging from 65 (70-watt lamp) to 125 lumens per watt (1000-watt lamp). These values include ballast losses, and they are based on new, burned-in lamps.

Lamp Life

Lamp life of HID lamps varies considerably depending on type (HPS vs. metal halide), burning orientation, size, and configuration. Generally, in similar applications, most HID lamps offer a lamp life duration comparable to most fluorescent lamps and much greater than any incandescent lamp. Lamp life may range from 3000 hours, for the 1500-watt metal halide sports lamp, to 24,000 hours and more for some of the standard HPS lamps. Near the end of lamp life, many HID lamps will exhibit a noticeable degree of color shift, which may be objectionable in some applications.

Lamp life ratings for applicable HID lamps are listed in the appropriate lamp charts in this document. It should be noted that lamp manufacturers publish HID lamp life ratings based on 10 hours per start operation (most other lamps are rated at 3 hours per start).

Color Characteristics

Manufacturers have taken advantage of new technologies in recent years to improve the color characteristics of HID lamps considerably. This development has allowed lighting professionals to use HID lamps in an ever-widening range of applications. In terms of lamp color temperature (CCT) and color rendering (CRI) capabilities, HID lamps can be summarized as follows:

Metal Halide Lamps

Some metal halide lamps are available in 2700-3200 K (warm) tones, but most lamps range from neutral to cool in color appearance, with a crisp white light of 3500-4300 K. Color rendering indices are usually between 65 and 70, although a few of the more recently-developed lamps achieve very high CRIs (up to 93).

High Pressure Sodium Lamps

Most HPS lamps have a distinctive, golden-pink color of 1900-2100 K, accompanied by a relatively poor CRI of less than 25. There are a few "deluxe" HPS products with a CRI of 65. In addition, "white" sodium lamps have color temperatures of 2500-2800 K and a CRI over 75. Neither deluxe nor white sodium lamps are as efficacious or as long-lasting as standard HPS lamps.

Temperature Sensitivity

Metal halide lamps are sensitive to low starting temperatures, and lamp life will be reduced if they are frequently started below -12 °C (10 °F). High pressure sodium lamps are fairly insensitive to temperature, and will start to about -30 °C (-22 °F).

Burning Orientation

Many HID lamps are designed to operate in a specific burning position, such as horizontal, vertical with base up, and vertical with base down. Lamp manufacturers usually designate the correct burning position for position-sensitive lamps in their catalogs. Operating HID lamps in burning positions other than those recommended by the manufacturer will adversely affect lamp life and lumen output. In particular, metal halide lamps are extremely sensitive to burning position. High pressure sodium lamps generally are not.

Other Applicable Technologies

HPS and metal halide lamps are the highest efficacy point sources in moderate lumen packages. However, in certain situations, other sources might be more applicable; these include:

- Halogen capsule, low voltage halogen projector, and infrared-reflecting halogen lamps, especially in small-scale display lighting situations
- Compact and full-size fluorescent lamps, particularly in general lighting and wall-washing situations

Current Products

As shown in Figure 8-2 HID lamps are available in a wide variety of sizes, shapes, and bases. HID lamp technology development is a continually evolving process, as manufacturers try to design lamp configurations and characteristics to meet an ever widening range of applications.

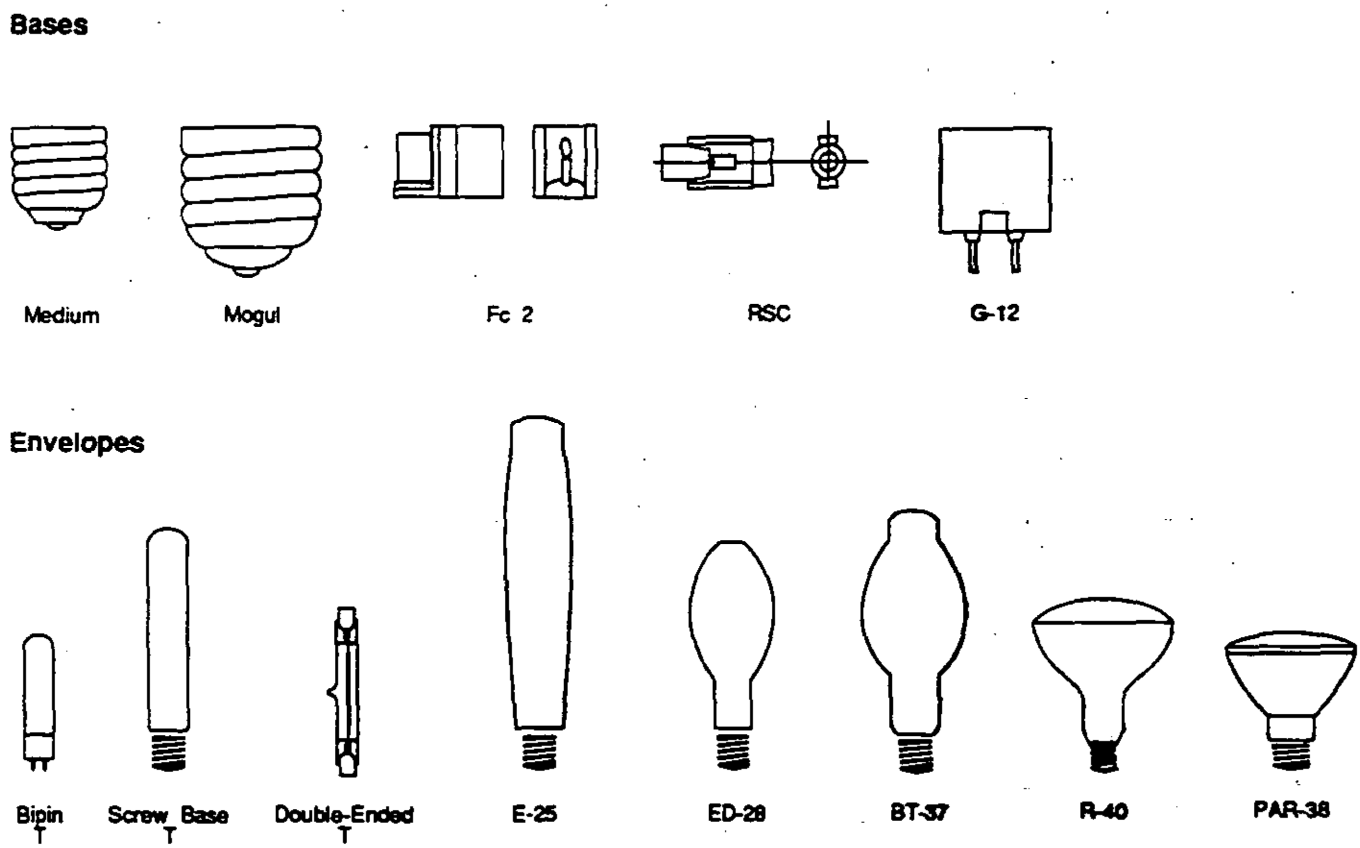


Figure 8-2
Typical HID Lamp Bases and Envelope Shapes (not to scale)

Metal Halide Products

Metal halide lamps were originally developed in 1965 for exterior and industrial lighting. Since that time the technology has expanded considerably to include lamps suitable for nearly any lighting application. Wattages range from 32 to 1500 watts, and a large number of envelope and base configurations are available, some of which are illustrated in Figure 8-3. Major variations of metal halide lamps include the following:

- Universal burning position lamps that are relatively insensitive to lamp physical orientation
- Position-specific lamps that have maximum efficacy and lamp life
- Choices of clear or phosphor-coated lamps in cool (3450-4100 K) color temperatures
- Optional warm (3000 K) phosphor-coated lamps in most sizes
- A few warm (3000-3200 K) clear lamps, especially in lower wattages
- Safety lamps that extinguish in the event of breakage of the outer envelope
- Lamps for open luminaires with internal arc rupture shields
- Silver-bowl lamps that minimize glare and light trespass from directional luminaires
- Compact lamps that produce a brilliant, high color rendering light in a comparatively small arc tube

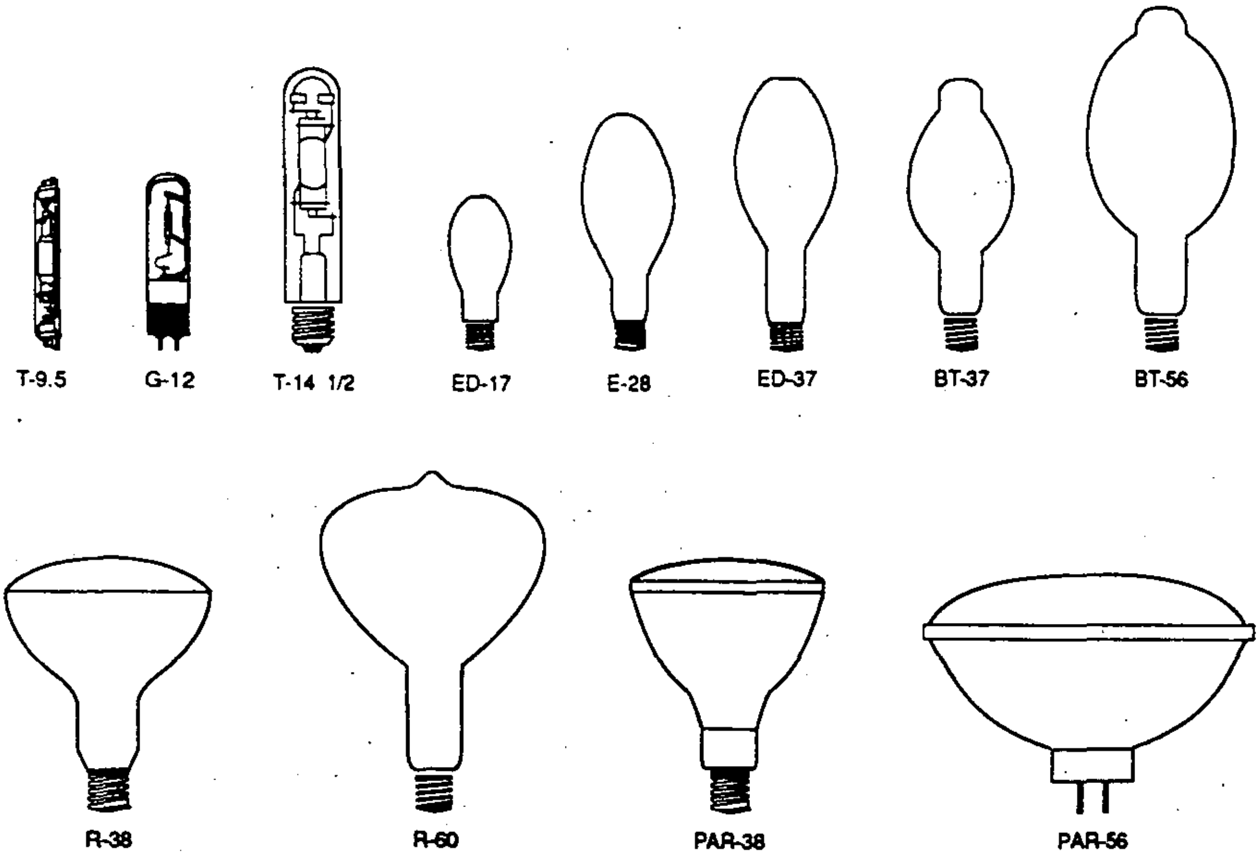


Figure 8-3
Metal Halide Lamp Configurations (not to scale)

Universal Position Screw Base Metal Halide Lamps (see Figure 8-4)

Because of their comparative insensitivity to operating position, the "universal" metal halide lamps are the most easily used. Generally, they perform best when the arc tube is in a vertical position, enjoying longer life and higher lumen output than when the arc tube is off vertical by more than 15 degrees.

Lamp color choice with universal metal halide lamps is generally limited to standard clear (4000-4500 K, 65 CRI) or coated (3700-4000 K, 70 CRI). Recent improvements include the addition of most wattages, as well as the development of medium-based compact lamps. These lamps operate on ANSI standard ballasts and generate 65-100 lumens per watt.

A few of these lamps are available with silver bowl arc-tube shields. These bowls act similarly to the familiar incandescent silver bowl lamps, by blocking unreflected arc tube radiation from the front hemisphere of the lamp.

Figure 8-4

Universal Position Screw Base Metal Halide Lamps

Watts	ANSI Code	Base	Envelope	CCT (K)	CRI	Coated or Clear	Initial Lumens (nominal)	Nominal Lamp Life (Hrs.)	Notes
50	M110	Medium	E/ED17	3700	70	Coated	3400	5000	
				4000	65	Clear	3400	•	
				4000	65	Clear	3200	•	Silver Bowl
70	M98	Medium	E/ED17	3700	70	Coated	5600	10,000	
				4000	65	Clear	5600	•	
				4000	65	Clear	5200	•	Silver Bowl
		Mogul	E/ED28	4000	65	Clear	5600	•	
100	M90	Medium	E/ED17	3700	70	Coated	7800	10,000	
				4000	65	Clear	7800	•	
				4000	65	Clear	7600	•	Silver Bowl
				5200	65	Clear	7000	7500	
		Mogul	E/ED28	4000	65	Clear	7800	10,000	
150	M57	Medium	E/ED17	3700	70	Coated	13,500	10,000	M107 Lamp
				4000	65	Clear	13,500	•	M107 Lamp
		Mogul	E/ED28	4000	65	Clear	13,500	•	M107 Lamp
175	M57	Medium	E/ED17	3700	70	Coated	15,000	10,000	
				4000	65	Clear	15,000	•	
		Mogul	E/ED28	3700	70	Coated	14,000	•	
				4000	65	Clear	14,000	•	
				4000	65	Clear	13,600	•	Silver Bowl
				5200	65	Clear	12,000	7500	
250	M58	Mogul	E/ED28	3700	70	Coated	20,500	10,000	
				4000	65	Clear	20,500		
				4000	65	Clear	20,000		Silver Bowl
				5200	65	Clear	19,000	7500	
			ED18	4000	65	Clear	20,500	10,000	
400	M59	Mogul	E/ED37	3700	70	Coated	36,000	20,000	
				4000	65	Clear	36,000	•	
				4000	65	Clear	35,000	•	Silver Bowl
				5200	65	Clear	32,500	15,000	
			ED28	3700	70	Coated	36,000	20,000	
				4000	65	Clear	36,000	•	
950	M47	Mogul	BT56	4000	65	Clear	105,000	12,000	
1000	M47	Mogul	BT56	3700	70	Coated	110,000	12,000	
				4000	65	Clear	110,000	•	
				4000	65	Clear	107,000	•	Silver Bowl
				5200	65	Clear	80,000	9000	
1500	M48	Mogul	BT56	3400	65	Clear	155,000	3000	
				4000	65	Clear	155,000	3000	

Notes:

Lumen and lamp life ratings are nominal and are based on specific manufacturer data. Check with individual manufacturers for exact data.
–All lamps must be used in enclosed luminaires;
–May be burned in any position, however,lamp life and lumen ratings apply to vertical burning position +/- 30 degrees;
–Lamp life is reduced to 75% of rated figures if burned in other positions; lumens decrease approximately 20% for horizontal burning position
–System input watts will vary depending on the ballast used. Contact the ballast manufacturer for actual input wattage.

In addition to universal burning position products, metal halide lamps are also available that are designed to operate either vertically or horizontally. When designed for a specific burning position, metal halide lamps can generate more light and offer more color options than are available with universal position lamps.

Vertical Position Screw Base Metal Halide Lamps

The vertical burning metal halide lamp is optimized for base-up, base-down, or base-up/base-down operation, primarily for use in downlights. In addition to standard clear (4000-4500 K) and coated (3700-4000 K) lamps, warm color (2700-3200 K) clear and coated lamps are available in various wattages. The newest products tend to be lower wattages with medium bases and smaller envelopes. One product - the 32-watt lamp - is designed specifically for operation on an electronic ballast.

A principal advantage of vertical burning lamps is efficacy. Lamps

Figure 8-5

Vertical Burning Screw-Based Metal Halide Lamps

Watts	ANSI Code	Base	Bulb Shape	CCT (K)	CRI	Coated or Clear	Burn Pos.	Initial Lumens (nominal)	Nominal Lamp Life (Hrs.)	Notes
32	M100	Medium	E17	3000	70	Coated	BU15	2500	10,000	Proprietary ballast
70	M98	Medium	ED17	3200	65	Clear	BUBD15	6000	10,000	
				3200	70	Coated	BUBD15	5600	10,000	
75	M101	Medium	ED17	3200	65	Clear	BU15	5600	5000	
				3200	70	Coated	BU15	5200	5000	
100	M90	Medium	ED17	3200	65	Clear	BUBD15	9000	10,000	
				3200	70	Coated	BUBD15	8500	10,000	
150	M57	Medium	ED17	3200	70	Coated	BUBD15	12,500	10,000	M107 type lamp
175	M57	Medium	ED17	3200	70	Coated	BU15	14,000	10,000	
		Mogul	ED23½	3200	65	Clear	BUBD15	16,600	10,000	
				3200	65	Coated	BUBD15	15,750	10,000	
			E/ED28	3200	65	Clear	BU15	14,000	10,000	
				4000	65	Clear	BU15	14,000	10,000	
				3200	70	Coated	BU15	13,000	10,000	
				3700	70	Coated	BU15	14,000	10,000	
250	M58	Mogul	E/ED28	3200	70	Coated	BU15	20,500	10,000	
				3700	70	Coated	BU15	23,000	10,000	
				4000	65	Clear	BU15	23,000	10,000	
400	M59	Mogul	E/ED37	3200	70	Coated	BU15	36,000	20,000	
				3700	70	Coated	BU15	40,000	20,000	
				4000	65	Clear	BU15	40,000	20,000	
				4000	65	Clear	BD15	40,000	20,000	
1000	M47	Mogul	BT56	3400	70	Coated	BU15	117,000	12,000	
				3900	65	Clear	BU15	117,000	12,000	
				3900	65	Clear	BU15	117,000	12,000	
1500	M48	Mogul	BT56	3400	65	Clear	HBU105	155,000	3000	
				3400	65	Clear	HBD105	155,000	3000	

Notes:
Lumen and lamp life ratings are nominal and are based on specific manufacturer data. Check with individual manufacturers for exact data.
Lamps must be used in enclosed fixtures.
System input watts will vary depending on the ballast used. Contact the ballast manufacturer for actual input wattage.
Lamps must be used within operating conditions listed:
- BUBD15 = base up or base down +/- 15 degrees
- BU15 = base up +/- 15 degrees (optimized for downlighting)
- BD15 = base down +/- 15 degrees (optimized for uplighting)
- HBU105 = horizontal to base up +/- 105 degrees (optimized for sports lighting)

generate 70-110 lumens per watt, or about 10% more than universal burning lamps. However, operation in any other position will reduce both lamp life and lumen output.

Performance characteristics of vertical position screw base lamps are noted in Figure 8-5.

Horizontal Position Screw Base Metal Halide Lamps **(See Figure 8-6)**

As in vertical burning metal halide lamps, optimum lamp design in horizontal lamps is achieved when operating position is predetermined. Horizontal high output or "super" lamps often have bowed arc tubes, and use a position-fixing pin in the base.

Figure 8-6

High Output Horizontal Burning Position Mogul Screw Base Metal Halide Lamps

Watts	ANSI Code	Bulb Shape	CCT (K)	CRI	Coated or Clear	Burn Pos.	Initial Lumens (nominal)	Nominal Lamp Life (Hrs.)
175	M57	E/ED28	3200	70	Coated	HOR45	14,000	10,000
			3700	70	Coated	HOR45	15,000	10,000
			4000	65	Clear	HOR45	15,000	10,000
			4200	70	Coated	HOR45	15,000	10,000
			4700	65	Clear	HOR45	15,000	10,000
250	M58	E/ED28	3200	70	Clear	HOR45	20,500	10,000
			3700	70	Coated	HOR45	23,000	10,000
			4000	65	Clear	HOR45	23,000	10,000
400	M59	E/ED37	3200	70	Coated	HOR45	36,000	20,000
			3700	70	Coated	HOR45	40,000	20,000
			4000	65	Clear	HOR45	40,000	20,000
			4000	65	Clear	HOR20	40,000	20,000
			4000	65	Clear	HOR20	40,000	20,000
1000	M47	BT56	3400	65	Clear	HOR60	117,000	12,000
1500	M48	BT56	3400	65	Clear	HOR60	162,000	3000
1650	*	BT56	3400	65	Clear	HOR60	177,000	3000

Notes:
All lamps have a special mogul base.
Lumen and lamp life ratings are nominal and are based on specific manufacturer data. Check with individual manufacturers for exact data.
System input watts will vary depending on the ballast used. Contact the ballast manufacturer for actual input wattage.
Lamps must be used in enclosed fixtures.
Lamps must be used within operating conditions listed:
-HOR45 = horizontal +/- 45 degrees
-HOR20 = horizontal +/- 20 degrees (optimized for signs)
-HOR60 = horizontal +/- 60 degrees (more flexible for sports)
* indicates non-standard type

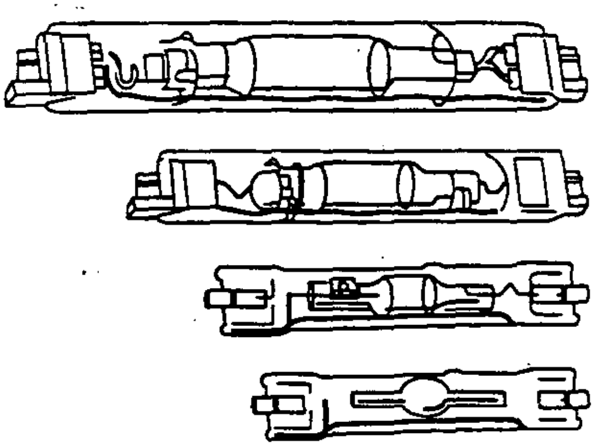


Figure 8-7

Double Ended Metal Halide Lamps with FC2 and RSC Bases

called a prefocus or position-orienting mogul (POM) base. This base and matching socket assure correct positioning of the lamp.

Since these lamps are primarily used in outdoor lighting, the smallest wattage product available is 175 watts. Special versions have been developed for signs and sports lighting. The most popular metal halide lamp colors are offered (3200 K coated, 3700 K coated, and 4100 K clear). As for vertical lamps, output is 70-110 lumens per watt.

Horizontal Position Double-Ended Metal Halide Lamps

Double-ended metal halide lamps in compact packages, illustrated in Figure 8-7, were originally introduced in Europe and have been very successful there. Some manufacturers produce these lamps with rare earth metals, resulting in lamps with very high CRIs of 80 or more, while others make the lamps with the more conventional 65-70 CRI associated with metal halide technology. The lamps with lower CRIs may be less sensitive to American power supply variations than the higher CRI lamps. These lamps operate in the range of 65-95 lumens per watt, and the 70-watt lamp with electronic ballast achieves about 75 lumens per watt – more than 10% more than with magnetically-ballasted operation. In addition, the 70-watt lamp operated on the electronic ballast virtually assures consistent light color and lamp life. Moreover, the reduced ballast package lends itself to smaller luminaires, especially track lighting equipment. An electronic ballast for the 150-watt lamp is rumored to be in development at this time.

Figure 8-8

Double-Ended Horizontal Burning Metal Halide Lamps

Watts	ANSI Code	Base	Bulb Shape	CCT (K)	CRI	Coated or Clear	Burn Pos.	Initial Lumens (nominal)	Nominal Lamp Life (Hrs.)	Notes
70	M85	RSC	T6.5	4200	65	Clear	HOR45	5500	7500	
				3500	65	Clear	HOR45	5500	7500	
				3000	65	Clear	HOR45	5000	7500	
				4200	85	Clear	HOR45	5500	10,000	
				3000	81	Clear	HOR45	5000	10,000	
100	M91	RSC	T7.5	4200	65	Clear	HOR45	6800	7500	
150	M81	RSC	T7.5	4200	65	Clear	HOR45	12,000	10,000	
				3500	65	Clear	HOR45	12,000	10,000	
				3000	65	Clear	HOR45	11,500	10,000	
				4200	85	Clear	HOR45	11,250	10,000	
				3000	81	Clear	HOR45	11,000	10,000	
250	M103	RSC	T9.5	4200	65	Clear	HOR45	20,000	10,000	Special Igniter
				4200	85	Clear	HOR45	20,000	10,000	Special Igniter
	M80	RSC/Fc2	T9.5	5400	93	Clear	HOR45	19,000	10,000	
				4200	85	Clear	HOR45	20,000	10,000	
				4200	65	Clear	HOR45	20,000	10,000	
				3500	65	Clear	HOR45	20,000	10,000	
400	M108	RSC	T10	4200	65	Clear	HOR45	34,000	15,000	Special Igniter
		Fc2D	T10	4200	65	Clear	HOR45	40,000	15,000	Special Igniter
		Fc2	T10	5400	93	Clear	HOR45	33,000	10,000	
1000	M47*	RSC	T9.5	3800	65	Clear	HOR15	100,000	3000	Special Igniter
1500	M48*	RSC	T7.5	3800	65	Clear	HOR15	150,000	2000	Special Igniter
			T9.5	3800	65	Clear	HOR15	150,000	2000	Special Igniter

Notes:
Lumen and lamp life ratings are nominal and are based on specific manufacturer data. Check with individual manufacturers for exact data.
System input watts will vary depending on the ballast used. Contact the ballast manufacturer for actual input wattage.
Lamps must be used in enclosed fixtures with UV absorbing lens.
Lamps must be used within operating conditions listed:
-HOR45 = horizontal +/- 45 degrees
-HOR15 = horizontal +/- 15 degrees)
* lamps operate on a standard ballast with a special igniter

Double-ended lamps must be operated with the arc tube within 45 degrees of horizontal, end-to-end. Performance characteristics of these lamps are shown in Figure 8-8.

Open Fixture Screw Base Metal Halide Lamps

Most metal halide lamps require enclosed luminaires to protect people and property from lamp rupture. Although rare, there are documented cases of metal halide lamps exploding. In most instances, this has occurred with near end-of-life lamps that have been continuously operated without having been switched off. These rare instances affect luminaire design requirements and restrictions.

There are a few metal halide lamps that are listed for non-enclosed use. These lamps typically employ an inner glass shield that can contain a violent failure within the combination of the inner shield and the normal bulb envelope. This technology is especially important for vertical position lamps, because many downlights in high ceilings are relamped using extension poles, and the cover glass required for most metal halide lamps hampers this operation.

Figure 8-9

Open Fixture Screw Base Metal Halide Lamps (except PAR-38 lamps)

Watts	ANSI Code	Base	Bulb Shape	CCT (K)	CRI	Coated or Clear	Burn Pos.	Initial Lumens (nominal)	Nominal Lamp Life (Hrs.)
50	M110	Medium	E/ED17	3200	65	Clear	UNIV	3300	5000
				3200	65	Coated	UNIV	2800	5000
70	M98	Medium	E/ED17	3200	65	Clear	UNIV	5200	10,000
				3200	65	Coated	UNIV	4800	10,000
				3200	65	Clear	BUBD15	6000	10,000
				3200	65	Coated	BUBD15	5600	10,000
		Mogul	E/ED17	3200	65	Clear	BUBD15	6000	10,000
100	M90	Medium	E/ED17	3200	65	Clear	UNIV	8500	10,000
				3200	65	Coated	UNIV	8000	10,000
				3200	65	Clear	BUBD15	9000	10,000
				3200	65	Coated	BUBD15	8500	10,000
		Mogul	E/ED17	3200	65	Clear	BUBD15	9000	10,000
400	M59	Mogul	E/BT37	3200	70	Coated	BU15	35,000	20,000
				3500	70	Coated	BU15	35,500	20,000
				3700	65	Clear	BU15	35,500	20,000
1000	M47	Mogul	BT56	3400	65	Coated	BU15	110,000	12,000
				3400	65	Clear	BU15	110,000	12,000

Notes:

Lumen and lamp life ratings are nominal and are based on specific manufacturer data. Check with individual manufacturers for exact data.

System input watts will vary depending on the ballast used. Contact the ballast manufacturer for actual input wattage.

Lamps may be used in open fixtures.

Lamps must be used within operating positions listed:

- -BUBD15 means base up or base down +/- 15 degrees
- -BU15 means base up +/- 15 degrees (optimized for downlighting)
- -UNIV = universal burning position; values given are vertical burning; horizontal life 25% less, horizontal lumens 15% less

Most open fixture lamps are designed for universal or vertical burning. There is a slight reduction in lumen output as compared to standard vertical burning lamps.

Performance characteristics of open fixture metal halide lamps are described in Figure 8-9.

Instant Restrike Metal Halide Lamps

Metal halide lamps exhibit fairly long warm-up and restrike times, generally the longest of all standard HID lamps. Even a momentary fluctuation of input power can cause a 10-15 minute interruption to the space being illuminated. For applications where such a possibility is intolerable (such as lighting for televised professional sports), an immediate restrike is needed. Instant restrike metal halide lamps are manufactured for such applications.

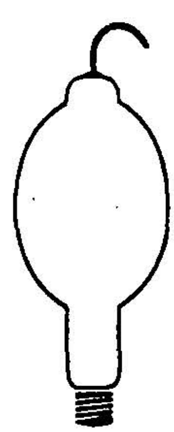


Figure 8-10

Instant Restrike Metal Halide Lamp

By building the lamp, ballast and socket to withstand extremely high voltages (up to 30,000 volts), metal halide lamps can be reignited "hot", returning to full light in seconds. Designed for the larger envelopes and wattages, instant restrike lamps utilize special wiring of the lamp to allow for the high voltage reignition across the arc tube. A separate anode wire, as shown in Figure 8-10 carries the 30,000 volt pulse without failing. Instant restrike metal halide lamps are described in Figure 8-11.

Figure 8-11

Instant Restrike Screw Base Metal Halide Lamps

Watts	ANSI Code	Base	Bulb Shape	CCT (K)	Burn Pos.	Initial Lumens (nominal)	Nominal Lamp Life (Hrs.)	Notes
175	M57	Mogul	BT28	4000	UNIV	14,000	10,000	
250	M58	Mogul	BT28	4000	UNIV	20,500	10,000	
400	M59	Mogul	BT37	4000	UNIV	36,000	20,000	
1000	M47	Mogul	BT56	4000	UNIV	110,000	12,000	
1500	M48	Mogul	BT56	3400	HBU105	155,000	3000	
		PO Mogul	BT56	3400	HOR60	162,000	3000	
1650	n.a.	PO Mogul	BT56	3400	HOR60	177,000	3000	Not-standard wattage

Notes:
Lumen and lamp life ratings are nominal and are based on specific manufacturer data. Check with individual manufacturers for exact data.
System input watts will vary depending on the ballast used. Contact the ballast manufacturer for actual input wattage.
All lamps listed are clear and have a CRI of 65.
Lamps must be used in enclosed fixtures.
Lamps used with special restrike igniter requiring fixture safety interlock and special high voltage wiring to anode cap.
Lamps must be used within operating positions listed:
-UNIV = universal burning position
-HOR60 = horizontal +/- 60 degrees
-HBU105 = horizontal to base up +/- 105 degrees (optimized for sports lighting)
n.a. = not available

Universal Position Directional Metal Halide Lamps

Directional metal halide lamps utilize familiar R and PAR lamp shapes to provide metal halide efficiency in a compact enclosure with its own reflector. Only in the last few years have these lamps become available in lower wattages. Now, metal halide directional lamps can be used in many applications previously limited to low-efficacy incandescent or mercury vapor lamps.

Metal halide PAR-38 lamps are especially important because they can be operated without a protective cover glass. This permits the lamp to be used in track lights, landscape lights, and other similar applications. The lack of a cover glass also makes relamping and maintenance easier.

The metal halide R lamps require a cover glass, but provide a reasonable-cost alternative for situations such as landscape lighting. The larger metal halide PAR-56 and PAR-64 lamps also require a cover glass, but offer relatively compact sources of high intensity, energy-efficient light. These could be particularly effective when used in recessed, track, and surface-mounted general and highlighting applications.

Note in Figure 8-12 that most metal halide directional lamps have shorter lamp lives than standard metal halide lamps.

High Pressure Sodium Lamps

High pressure sodium lamps were developed and introduced in 1968 as energy-efficient sources for exterior, security, and industrial lighting applications. HPS lamps were rapidly placed into street lighting service, and most street lighting today is HPS. HPS lamps are the most efficient of the white HID lamp sources, and they are useful in most applications where high color rendering is not a crucial concern.

Figure 8-12

Universal Burning Position Directional Metal Halide Lamps

Watts	ANSI Code	Base	Bulb Shape	CCT (K)	CRI	Beam Type	Beam Spread Degrees	Center Beam CP (nominal)	Nominal Lamp Life (Hrs.)	Notes
70	M98	Medium	R40	4000	65	Spot	15	60,000	10,000	
						Flood	70	1500	10,000	
		Med. Skt.	PAR38	4300	65	Spot	15	40,000	5000	Open fixture
						Flood	35	12,000	5000	Open fixture
				3200	65	Spot	20	18,000	7500	Open fixture
						Flood	35	10,000	7500	Open fixture
						Flood	65	3000	7500	Open fixture
		Mog. Prong	PAR56	4300	65	Spot	20	105,000	5000	
100	M90	Medium	R40	4000	65	Spot	15	80,000	10,000	
						Flood	70	3300	10,000	
		Med. Skt.	PAR38	3200	65	Spot	20	26,000	7500	Open fixture
						Flood	35	12,000	7500	Open fixture
						Flood	65	4500	7500	Open fixture
		Mog. Prong	PAR56	4300	65	Spot	20	106,000	5000	
175	M57	Medium	R40	4000	65	Spot	15	95,000	10,000	
						Flood	70	6500	10,000	
		Mog. Prong	PAR56	4300	65	Spot	20	108,000	5000	
250	M58	Mog. Prong	PAR64	4300	65	Spot	15	210,000	5000	
400	M59	Mog. Prong	PAR64	4300	65	Spot	30	120,000	5000	
1000	*	Mog. Prong	PAR64	4000	88	Spot	8	1,500,000	5000	*CSI Type
				5600	92	Spot	8	1,200,000	5000	*CID Type

Notes:
Lumen and lamp life ratings are nominal and are based on specific manufacturer data. Check with individual manufacturers for exact data.
System input watts will vary depending on the ballast used. Contact the ballast manufacturer for actual input wattage.
Except where noted, lamps must be used in enclosed fixtures.
Lamp performance values listed for the following burning positions:
-R lamps, for vertical arc tube +/- 30 degrees
-PAR lamps, for horizontal arc tube +/- 45 degrees
Lamp life, lumens approximately 80% 75% in other positions.

Unlike metal halide lamps, HPS lamps do not contain starting electrodes. Due to the HPS ballast's electronic starting circuit, warm-up and restrike periods are much shorter than those of metal halide lamps.

Universal Position Screw Base HPS Lamps

HPS lamps, unlike most metal halides, do not require enclosure except to prevent moisture from accumulating on the lamp. This makes HPS lamps especially easy to use in many fixture types. Moreover, the virtual insensitivity of HPS lamps to operating position means that fewer lamp types are needed as compared to metal halide.

Lamp color temperature in HPS lamps does not vary much. While the "deluxe" HPS lamp has a relatively high CRI (65) for HPS technology, its color temperature of 2100-2200 K is not much different from standard HPS, which varies between 1900 K and 2100 K. All HPS lamps except "white" sodium appear a golden-pink color, and are not recommended for non industrial interior lighting.

HPS lamps are offered in many wattages. Lumens per watt,

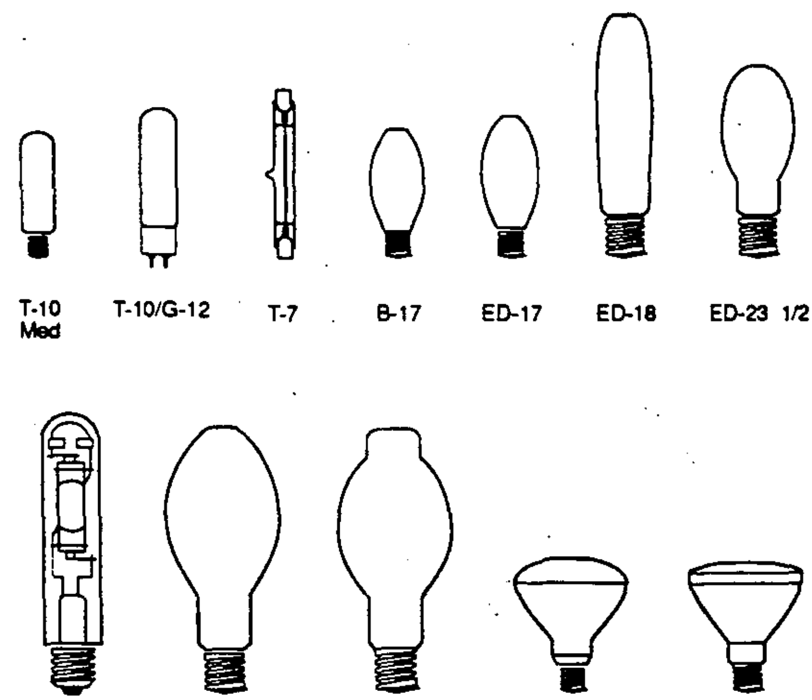


Figure 8-13
Typical High Pressure Sodium Lamp Configurations (not to scale)

ranging from 70 to 120 (including ballast), increases with wattage, . Electronic ballasts are rumored to be in development and will likely provide a small increase in system efficacy.

Some HPS lamps can be obtained with 2 arc tubes. These so-called "standby" lamps are a reasonable alternative to instant restrike circuits, providing rapid restrike cycles while offering extended lamp life. It should be noted that lamp warm-up time will still be in effect in the event of a power interruption. However, the lamp will not have to cool down before the second arc can be struck. These lamps are especially applicable for roadway and parking lot applications. In normal operation, standby lamps alternate operation between the arc tubes. This may in effectively double lamp life, although lamp life of these products has not been fully tested, and manufacturers' published lamp life values do not, as yet, reflect an increase for double arc tube lamps.

Performance characteristics of screw base HPS lamps are listed in Figures 8-14 and 8-15. "Deluxe" HPS lamps with a CRI of 65 are described in Figure 8-14, while standard screw base HPS lamps are noted in Figure 8-15.

Figure 8-14

"Deluxe" Type Universal Burning Position HPS Lamps

Watts	ANSI Code	Base	Bulb Shape	Coated or Clear	Initial Lumens (nominal)	Nominal Lamp Life (Hrs.)
70	S62	Medium	B17	Clear	3800	15,000
				Coated	3600	15,000
			ED17	Clear	4400	15,000
				Coated	4180	15,000
		Mogul	ED23½	Clear	4400	15,000
				Coated	4180	15,000
100	S54	Medium	ED17	Clear	7300	15,000
				Coated	6940	15,000
		Mogul	ED23½	Clear	7300	15,000
				Coated	6940	15,000
150	S55	Medium	B17	Clear	10,500	15,000
				Coated	9900	15,000
			ED17	Clear	12,000	15,000
				Coated	11,000	15,000
		Mogul	E23½	Clear	10,500	15,000
				Coated	9900	15,000
			ED23½	Clear	12,000	15,000
				Coated	11,000	15,000
250	S50	Mogul	E/ED18	Clear	23,000	15,000
			E28	Coated	20,000	15,000
400	S51	Mogul	ED18	Clear	37,500	15,000
			E28	Clear	37,400	10,000
				Coated	35,500	10,000

Notes:
All lamps have CCT of approximately 2100-2200 K and CRI of 65.
Lumen and lamp life ratings are nominal and are based on specific manufacturer data. Check with individual manufacturers for exact data.
System input watts will vary depending on the ballast used. Contact the ballast manufacturer for actual input wattage.

Figure 8-15

Universal Burning Position Screw Base HPS Lamps

Watts	ANSI Code	Base	Bulb Shape	CCT (K)	CRI	Coated or Clear	Initial Lumens (nominal)	Nominal Lamp Life (Hrs.)	Notes
35	S76	Medium	E/B17	2000	18	Clear	2250	24,000	
				2000	18	Coated	2150	24,000	
			T10	2000	18	Clear	2100	24,000	
50	S68	Medium	E/B17	2050	20	Coated	3800	24,000	
				2050	20	Clear	4000	24,000	
			T10	2050	20	Clear	3700	24,000	
		Mogul	ED23½	2050	20	Clear	4000	24,000	
				2050	20	Coated	3800	24,000	
70	S62	Medium	E/B17	2050	20	Coated	5985	24,000	
				2050	20	Clear	6300	24,000	
			T10	2050	20	Clear	6300	24,000	
		Mogul	E/ED23½	2050	20	Coated	5985	24,000	
				2050	20	Clear	6300	24,000	
				2050	20	Clear	6300	24,000	
100	S54	Medium	B17	2050	20	Coated	8500	40,000	Double arc tube
				2050	20	Clear	9500	24,000	
		Mogul	E/ED23½	2050	20	Clear	9500	24,000	
				2050	20	Coated	8800	24,000	
				2050	20	Clear	9100	40,000	Double arc tube
150	S55	Medium	B17	2100	22	Coated	15,000	24,000	
				2100	22	Clear	16,000	24,000	
		Mogul	E/ED23½	2100	22	Clear	16,000	24,000	
				2100	22	Coated	15,000	24,000	
				2100	22	Clear	15,600	40,000	Double arc tube
	S56	Mogul	E28	2100	22	Clear	15,000	24,000	
200	S66	Mogul	E/ED18	2100	22	Clear	22,000	24,000	
				2100	22	Clear	22,000	40,000	Double arc tube
250	S50	Mogul	E28	2100	22	Coated	26,000	24,000	
			E/ED18	2100	22	Clear	27,500	24,000	
				2100	22	Clear	30,000	24,000	
				2100	22	Clear	27,500	40,000	Double arc tube
			T14.5	2100	22	Clear	29,000	24,000	
				2100	22	Clear	28,500	40,000	Double arc tube

Figure 8-15 (continued)

Universal Burning Position Screw Base HPS Lamps

Watts	ANSI Code	Base	Bulb Shape	CCT (K)	CRI	Coated or Clear	Initial Lumens (nominal)	Nominal Lamp Life (Hrs.)	Notes
310	S67	Mogul	E/ED18	2100	22	Clear	37,000	24,000	
400	S51	Mogul	E/ED37	2100	22	Coated	47,500	24,000	
			E/ED18	2100	22	Clear	50,000	24,000	
				2100	22	Clear	50,000	40,000	Double arc tube
			T14.5	2100	22	Clear	50,000	24,000	
				2100	22	Clear	50,000	40,000	Double arc tube
600	S106	Mogul	T16	2100	22	Clear	90,000	24,000	
750	S111	Mogul	BT37	2100	22	Clear	110,000	24,000	
1000	S52	Mogul	E-25	2100	22	Clear	140,000	24,000	
				2100	22	Clear	140,000	40,000	Double arc tube
			T21	2100	22	Clear	140,000	24,000	

Notes:
All lamps are universal burning position.
Lumen and lamp life ratings are nominal and are based on specific manufacturer data. Check with individual manufacturers for exact data.
System input watts will vary depending on the ballast used. Contact the ballast manufacturer for actual input wattage.

Figure 8-16

Universal Burning Position Directional High Pressure Sodium Lamps

Watts	ANSI Code	Base	Bulb Shape	CCT (K)	CRI	Beam Type	Beam Spread	Center Beam CP (nominal)	Nominal Lamp Life (Hrs.)	Notes
35	S76	Medium	R-38	2100	18	WFL	65 DEG	1000	16,000	
75	S62	Med. Skt.	PAR-38	2100	21	WFL	65 DEG	2200	10,000	
		Med. Prong	PAR-38	2100	21	WFL	65 DEG	2200	10,000	
		Medium	R-38	2100	65	WFL	65 DEG	1800	10,000	"Deluxe"

Notes:
Lumen and lamp life ratings are nominal and are based on specific manufacturer data. Check with individual manufacturers for exact data.
System input watts will vary depending on the ballast used. Contact the ballast manufacturer for actual input wattage.
These lamps are not weatherproof.

Universal Position Directional HPS Lamps (See Figure 8-16)

PAR and R-configured HPS lamps are useful for compact directional light sources, such as track lighting and outdoor lighting luminaires. The poor color rendition of these lamps, however, limits the usefulness to specific industrial and security floodlighting and general lighting applications.

Figure 8-17
Double-Ended High Pressure Sodium Lamps

Watts	ANSI Code	Base	Bulb Shape	CCT (K)	CRI	Coated or Clear	Burn Pos.	Initial Lumens	Lamp Life (Hrs.)	Notes
70	S88	RSC	T6.5	2100	22	Clear	HOR45	7000	10,000	Replaces M85 lamp
150	M81	RSC	T7.5	2100	22	Clear	HOR45	15,000	10,000	Replaces M81 lamp
250	S50	RSC	T7	2100	22	Clear	HOR45	27,000	24,000	
400	S51	RSC	T7	2100	22	Clear	HOR45	50,000	24,000	

Notes:
Lumen and lamp life ratings are nominal and are based on specific manufacturer data. Check with individual manufacturers for exact data.
System input watts will vary depending on the ballast used. Contact the ballast manufacturer for actual input wattage.
Lamps must be used within operating positions listed:
–HOR45 = horizontal +/- 45 degrees

Double-Ended HPS Lamps

The double-ended HPS lamp was designed to take advantage of luminaires and lighting installations originally designed for the double-ended metal halide lamp. The double-ended HPS lamp offers comparable lumen output, but offers HPS' longer lamp life and excellent lumen maintenance characteristics. These lamps, which are relatively uncommon at this time, are described in Figure 8-17.

White Sodium Lamps

White HPS lamps offer lamp life and lumen maintenance characteristics similar to those of other HPS lamps whose color temperatures and CRIs may be unsuitable for many interior spaces. However, ballast designs for "white" HPS lamps employ electronic circuits designed to increase color temperature and CRI. The color temperature of white sodium lamps, at 2600 K to 2800 K, closely resembles incandescent lighting. During the lamp's stable color-life, the color performance is more consistent and appealing than most metal halide lamps (including 3000 K lamps). Although efficacy is a relatively low 35-45 lumens per watt, the white sodium lamp is in many ways the best (if not the only) high-efficacy substitute for incandescent lamps.

Note that white sodium lamps are incompatible from manufacturer to manufacturer. No significant new white sodium products have been announced since the 1990 *Advanced Lighting Guidelines.* The performance characteristics of these lamps are described in Figure 8-18.

Figure 8-18
White Sodium Lamps

Watts	ANSI Code	Base	Bulb Shape	CCT (K)	CRI	Coated or Clear	Initial Lumens	Lamp Life (Hrs.)
35	S99	PG12 Bipin	T10	2700	80	Clear	1250	10,000
50	S104	PG12 Bipin	T10	2700	80	Clear	2300	10,000
		Medium	ED17	2700	80	Coated	2190	10,000
95	Special	Medium	T10	2700	80	Clear	5200	10,000
95	Special	Medium	B17	2700	80	Coated	4800	10,000
100	S105	PG12 Bipin	T10	2700	80	Clear	4700	10,000
		Medium	ED17	2700	80	Coated	4470	10,000

Notes:
Lumen and lamp life ratings are nominal and are based on specific manufacturer data.
Check with
individual manufacturers for exact data.
System input watts will vary depending on the ballast used. Contact the ballast manufacturer for
actual input wattage.

Figure 8-19
Interchangeable HID Lamps

Watts	Replaces	ANSI Ballast	Bulb Shape	CCT K	CRI	Coated or Clear	Burn Pos.	Initial Lumens	Lamp Life (Hrs.)	Notes
					Metal Halide Lamps					
250	250w HPS	S50	E/ED28	3700	70	Coated	BU15	20,500	5000	Must be enclosed
				4000	65	Clear	BU15	20,500	5000	Must be enclosed
400	400w HPS	S51	E/ED28	4000	65	Clear	UNIV	36,000	5000	
			E/ED37	3700	70	Coated	BU15	40,000	10,000	
				4000	65	Clear	BU15	40,000	10,000	
325	400w MV	H33*	E/ED37	4000	65	Clear	UNIV	28,000	20,000	
				3700	70	Coated	UNIV	28,000	20,000	
400	400w MV	H33*	E/ED37	4000	65	Clear	UNIV	36,000	15,000	Works on M59 Ballast
				3700	70	Coated	UNIV	36,000	15,000	Works on M59 Ballast
950	1000w MV	H15/H36	BT56	4000	65	Clear	BU15	100,000	12,000	Works on M47 Ballast
				4000	65	Clear	BD15	100,000	12,000	Works on M47 Ballast
					High Pressure Sodium Lamps					
150	175w MV	H39	BT28	2100	22	Clear	UNIV	13,000	24,000	
215	250w MV	H37	BT28	2100	22	Clear	UNIV	20,000	16,000	
360	400w MV	H33	BT37	2100	22	Clear	UNIV	38,000	12,000	
880	1000w MV	H15/36	E25	2100	22	Clear	UNIV	102,000	12,000	

Notes:
*Not all mercury ballasts are suitable for interchangeable lamps.
Metal halide lamps values are for vertical burning position.
Open fixtures for all HPS and vertical metal halide lamps; other metal halide positions require suitable enclosed luminaire.
Lumen and lamp life ratings are nominal and are based on specific manufacturer data. Check with individual manufacturers for exact data.
System input watts will vary depending on the ballast used. Contact the ballast manufacturer for actual input wattage.

Interchangeable Lamps

Metal halide lamps have superior color when compared to either mercury vapor or high pressure sodium technologies. For interior spaces where either of the poorer color lamps were originally used, it may be desirable to retrofit with metal halide without having to change the ballasts in the existing luminaires. Specific products are available in a few configurations and wattages to serve this function.

Similarly, some high pressure sodium lamps can be retrofitted into existing mercury vapor luminaires, particularly street lights, with reduced wattage and substantially increased lumen output. The lamps are available from most manufacturers to replace the traditional high wattage mercury street light lamps.

Performance characteristics of exchangeable metal halide and HPS lamps are noted in Figure 8-19.

Application Guidelines

HID lamps are point sources that lend themselves to projection and floodlighting situations, as well as to general illumination. The best interior applications are those where lights are left on for long periods or are controlled by a time switch. Examples would include manufacturing, corridor, and display lighting, as well as commercial area lighting. Some of the best applications for HID lamps are in all kinds of exterior lighting sources. HID sources are especially suitable for roadway, architectural, landscape, parking lot, security, and sports lighting.

Typical Applications

In general, HID lamps are best applied in one of the following ways:

- *Energy-Efficient Flood and Display Lighting* In suitable modern luminaires, HID lamps can be used for a wide variety of display and floodlighting situations, including track, recessed, and surface installations.

- *Energy-Efficient Lamps in General Lighting Luminaires* As long as switching is not a concern, a wide variety of opportunities exist to use HID lamps for area lighting in both interior and exterior situations. HID lamps are particularly well-suited to large rooms with high ceilings, such as gymnasiums, industrial plants, and warehouses.

General Limitations

All HID lamps require warm-up and restrike periods, so applications requiring frequent switching should not utilize HID lamps. Additionally, as noted previously, lamps of these types can only be dimmed with highly-specialized dimmers and ballasts. The effect of dimming is not nearly as appealing or as extensive as it is with incandescent or fluorescent light sources. Lamp efficacy and color stability suffer when HIDs are operated at less than full output.

Residential Applications

Because frequent switching is common to residential operation, HID lamps are not commonly used in homes. Nevertheless low wattage HID lamps may be useful in outdoor security and landscaping lighting applications, particularly if these sources are controlled by timers or photocells.

Commercial Applications

HID lamps offer the designer an alternative to incandescent downlights, uplights, and accent lights. Unlike fluorescent alternatives, HID lamps are point sources of light that give sparkle to polished surfaces and produce dramatic shadowing when used to accent displays. The compact lamp size of the smaller HID lamps allows for the use of many traditional luminaire types and shapes while employing a reasonable lumen package.

Special Interior Applications

The best interior applications for HID lamps are for corridor and lobby downlighting, commercial wall washing, lobby and office uplighting, and commercial and general lighting. The smaller HID lamps are valuable in accent and display lighting applications, as well. In addition, some types of highly decorative fixtures, such as wall sconces and pendant chandeliers, can be designed for compact HID lamps.

Exterior Applications

There is a wide range of exterior applications for HID lamps. In addition to those listed previously, HID lamps can be used in many landscape applications, such as bollards and tree uplights, as well as in wall lights, step lights, and architectural facade and floodlighting luminaires. The large 1500-watt metal halide lamp with a lamp life of 2000 to 3000 hours is widely used in sports lighting applications where television cameras are used.

Additional Application Considerations

There are several precautions to be considered when employing HID lamp technology in certain situations. Manufacturers' literature on this subject is extensive, and trouble shooting guides, engineering, and technical bulletins are available. Some of the most important considerations are noted below.

Lamp Restrike Time and Backup Lighting

In HID applications where a brief power outage could cause hazardous conditions or a major manufacturing shutdown, and where no backup non-HID emergency lighting system is in place, it is a good idea to specify that some portion of the luminaires be furnished with either instant restrike or quartz backup lamps. This will insure that some type of backup lighting will be in place until the HID lamps can be reignited.

Strobe Effects in Manufacturing Environments

All HID lamps are turned on and off 120 times per second in synchronization with the 60-Hz alternating current power supply. Because of this, the use of HPS lamps in general lighting luminaires near rotating machinery may produce a stroboscopic effect, making the machinery appear to be motionless – a potentially hazardous situation. This can occur when the moving object rotates at any speed which is a multiple of 60 (i.e. 2400 revolutions per minute). Strobe effects of this type can be mostly eliminated by the proper phasing of the luminaire power supply circuits, so that none of the machinery is lighted solely by luminaires on the same phase circuit.

Continuously-Operated Metal Halide Lamps

Metal halide lamps may rupture if they are operated continuously (24 hours/day, 7 days/week). In continuous operation-type applications, metal halide lamps should be extinguished at least once a week for a minimum of 15 minutes to avoid the risk of potentially violent rupture. If this is not feasible, then a different light source should be specified, or the metal halide lamps should be group relamped well in advance of rated lamp life.

Replacement of HPS Lamps

HPS lamps signal the end of lamp life by cycling – starting, warming up, going out, cooling down, and starting again. The electronic starting circuit in HPS ballasts continues to pulse when the lamp is removed from the luminaire Therefore, HPS luminaires should not be left energized when lamps are not in place, and cycling lamps should be replaced, or damage to the starter and ballast will occur. A special device is available to prevent HPS cycling at the end of lamp life. (Note: this precaution also applies to other HID lamps – such as medium-based metal halide lamps – operated by external starting circuitry.

Example

A high-ceilinged hotel lobby might employ recessed incandescent downlights supplied with 250-watt PAR-38 quartz lamps to provide general illumination for the space. If, instead, 70-watt double-ended metal halide (3000 K, 81 CRI) electronically-ballasted lamps were used, the following benefits could be realized:

- > 160 watts per socket saved, including ballast losses
- Fewer luminaires needed, due to increased lumen output (5500 lumens to 3300 lumens)
- Decreased maintenance charges for relamping, due to increased lamp life of 67% (10,000 hours to 6000 hours)

The metal halide luminaires in this application will use much less energy than the incandescent downlights, while providing an essentially similar aesthetic to the hotel lobby. Although the initial costs for luminaires and lamps will be higher than would be the case for the incandescent design, the reduced quantity of luminaires needed, combined with the energy savings achieved by the design, will more than offset the higher start-up cost, while producing significant long-term savings.

Guideline Specifications

Specifications of HID lamps should generally follow a designation system authorized and determined by ANSI. All such designations begin with a letter ("M" for metal halide, "S" for HPS), followed by an ANSI number identifying the electrical characteristics of that lamp's ballast. After the number, there is a letter-number combination to designate the lamp envelope shape and size (ED-17, BT-28, etc.). Optional added designations may include base type, wattage, clear or coated, warm or neutral color, and/or standard or deluxe color rendering. For instance, a 70-watt double-ended metal halide warm (3000 K) colored lamp with deluxe color rendering could be designated as:

M85/T7/RSC/70/WDX

Similarly, a standard 250-watt mogul-based ellipsoidal-shaped HPS lamp with diffusing coating might bear the following designation:

S50/E28/MOG/250/COATED

There are important and popular HID lamps for which ANSI designations are still pending. This is true for many of the more recent lamp developments such as compact metal halide and white sodium lamps. In these cases, it may be necessary to use a proprietary specification to designate acceptable lamp and ballast manufacturers.

FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

TEMA 4

BALASTROS.

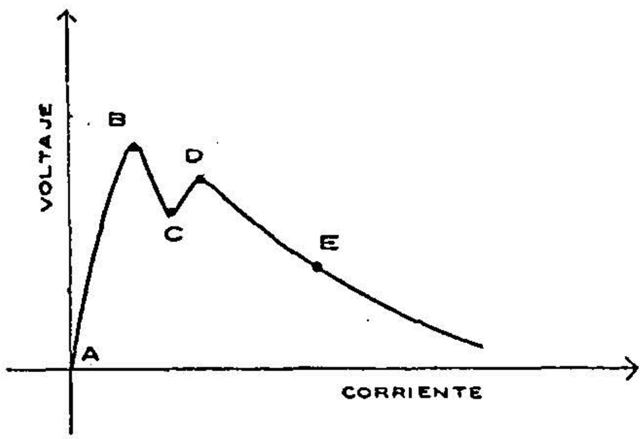
ING. ERNESTO MENDOZA.

E L B A L A S T R O

Finalidad: El transformador de alta reactancia de dispersión.

Tipos de Balastros.

El fenómeno de la descarga eléctrica en gas es un fenómeno complejo, y la gráfica siguiente nos da idea del comportamiento de las cargas cuando se lleva a cabo el fenómeno.



La información que se puede obtener de la gráfica y que nos interesa exponer, se encuentra entre los puntos D y E que es la región de operación normal de la lámpara fluorescente.

En esta parte de la gráfica se ve que habiéndose superado el voltaje Vx el gas presenta una región de resistencia negativa, y en donde la corriente eléctrica a través del gas crece teóricamente hasta el infinito.

Es debido a ésto que se justifica la existencia de los balastros, que son dispositivos que sirven primordialmente para -- mantener la corriente eléctrica a través de la lámpara, en un rango de valores, que permiten a la lámpara operar satisfactoriamente y sobre todo protegerla de la destrucción.

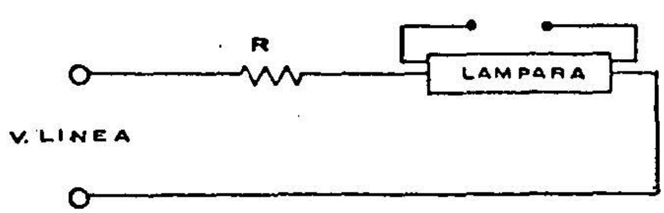
El vocablo balastro se deriva de la palabra inglesa "ballast" que significa lastre.

De acuerdo a la definici[illegible] norma CCONNIE - 16.2 1 tiene, el balastro, "es un dispositivo que, por medio de inductancias, capacitancias, o resistencias, solas o en combinación, - limita la corriente de lámparas fluorescentes al valor requerido para su operación correcta y también, cuando es necesario -

suministra la tensión y corriente de arranque, y en el caso de balastros para lámparas de arranque rápido, suministra la tensión para calentamiento de los catódos".

En principio, un balastro puede ser cualquier elemento que limita la corriente, como por ejemplo, una resistencia, una capacitancia, una inductancia ó una combinación de los elementos anteriores.

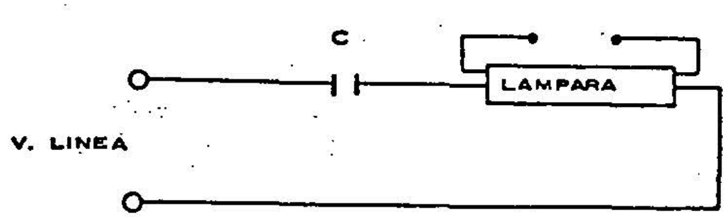
El hecho de usar lámparas fluorescentes obedece a que su eficiencia lumínica es mayor que las incandescentes debido a que éstas últimas emiten un gran porcentaje de radiación en la región infrarroja es decir en forma de calor; entonces si nosotros usamos un balastro a base de resistencias, lo que logramos es crear pérdidas, y no tiene caso usar una lámpara fluorescente que es incluso más cara, si la eficiencia del conjunto balastro-lámpara es parecida a una incandescente.



El usar un balastro a base de capacitancias no es económico debido a las bajas frecuencias de transmisión de energía -- que se utilizan comunmente (50 ó 60 Hz), además de que la forma de onda de la corriente de la lámpara se deformaría - notablemente, creando picos que dañarían a la lámpara .

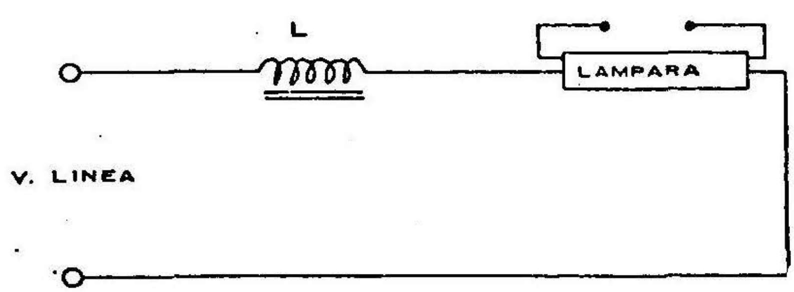
En otras palabras, se necesitarían valores altos de capaci_ tancia para poder proporcionar a la lámpara una corriente- nominal de operación muy deformada.

Sin embargo el capacitor resulta ser buen balastro desde - 400 Hz en adelante.



El tipo restante de balastro es una "reactancia inductiva" También conocida como inductancia, inductor, o bobina de - choque.

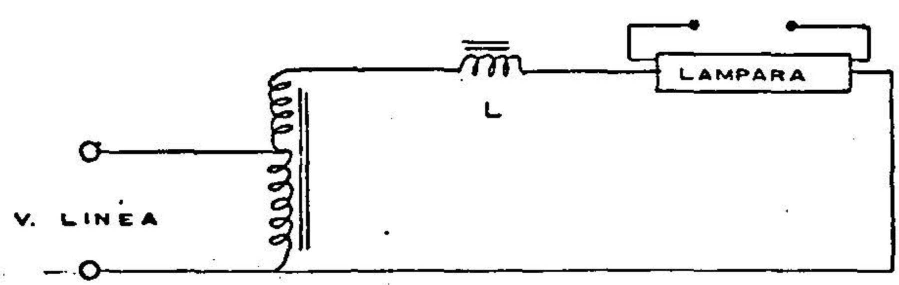
De los tipos de balastros antes mencionados, éste es sin duda el más satisfactorio y el más económico, y en la actualidad casi todos los balastros están formados por inductancias, o combinaciones de éstas con capacitancias.



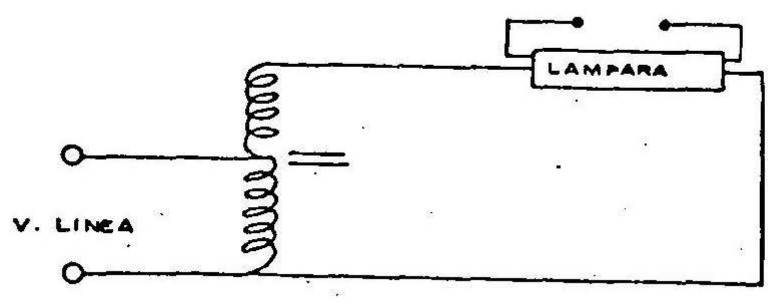
INDUCTANCIA SERIE

EL AUTOTRANSFORMADOR DE ALTA REACTANCIA DE DISPERCION

Los circuitos mostrados anteriormente, funcionan en redes de alimentación cuyo voltaje es mayor que el voltaje mínimo de encendido de la lámpara, sin embargo cuando éste último es superior al de línea, se necesitaría, además de la inductancia serie, un transformador o autotransformador que elevara la tensión hasta un valor suficiente para encender la lámpara tal como se muestra en la siguiente figura:

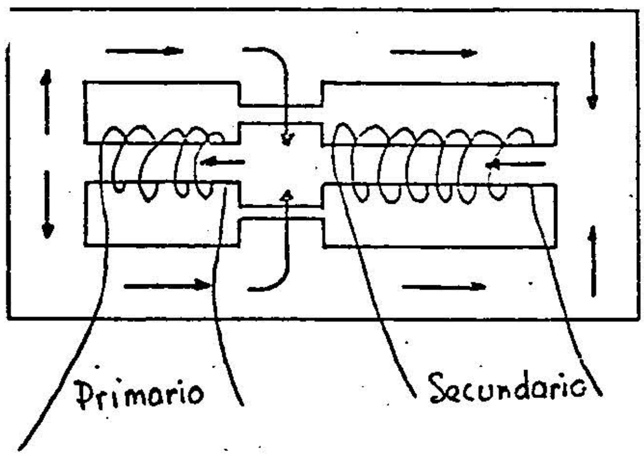


Esta combinación es completamente satisfactoria eléctricamente, aunque excesivamente costosa. Probablemente el avance técnico de más significación en el campo de la fabricación de balas -- tros para lámparas fluorescentes y en general para lámparas - de descarga eléctrica en gases, fué el desarrollo de los balas tros "autotransformadores de alta reactancia de dispersión" - que son las que se utilizan actualmente. Dicho de forma ele - mental, el balastro autotransformador de alta reactancia combi na los elementos del circuito de la Fig. (autotransfor mador y bobina de choque) , en un solo núcleo, lo que disminu - ye el tamaño y costo, y aumenta la eficiencia del circuito. Es te tipo de balastro se muestra esquemáticamente en la siguiente figura.



AUTOTRANSFORMADOR ALTA REACTANCIA

En la figura se muestra la estructura del núcleo de acero y de los devenados, así como las trayectorias de las Líneas Magnéticas.



DIBUJO ESQUEMATICO

Nótese en la figura que el autotransformador de alta reactancia tiene 2 devenados, uno primario y otro secundario, separados mediante entrehierros magnéticos.

En un transformador ordinario tendríamos ambos devanados uno encima del otro, ya que en este caso resulta importante que todo el flujo magnético que produce el devanado primario pase a través del devanado secundario. Al embobinar ambos devanados uno encima del otro se logra ésto fácilmente. Sin embargo en un autransformador de alta reactancia, al tener separados mediante entrehierros los devanados primario y secundario, intencionalmente obligamos que parte del flujo magnético creado por el devanado creado por el devanado primario, pase a través de los entrehierros, y no pase a a través del devanado secundario. Esta alta dispersión del flujo magnético creada a propósito, manifiesta su efecto en forma de una reactancia inductiva parásita en serie con el circuito secundario y es precisamente esta reactancia inductiva la que controla la corriente eléctrica a través de la lámpara.

TIPOS DE BALASTROS

En resumen, para poder iniciar la descarga eléctrica en un tubo fluorescente, se necesitan 2 condiciones:

1. Que exista entre sus extremos un voltaje igual o mayor que el mínimo necesario especificando por el fabricante de lám paras.

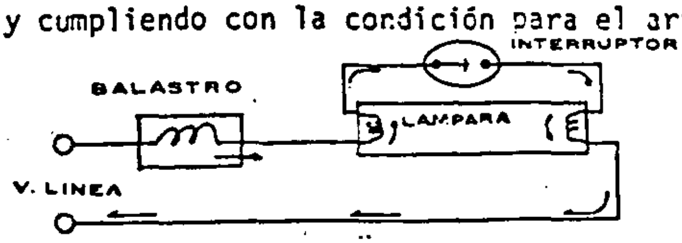
2. Que sus cátodos tengan al momento de arranque disponibles - electrones libres.

Esta segunda condición se puede lograr de tres formas diferentes y da lugar a la división de las lámparas y de los balas -- tros en tres tipos de encendido.

a) Encendido Precalentado
b) Encendido rápido
c) Encendido instantáneo

a) Encendido Precalentado:

Se conecta un interruptor térmico entre dos terminales - opuestas entre dos terminales opuestas de las lámparas, de tal manera que cuando está frío (el interruptor) - se pone en corto circuito, y origina que una corriente- circule a través de los cátodos de la lámpara calentandolos y cumpliendo con la condición para el arranque; -

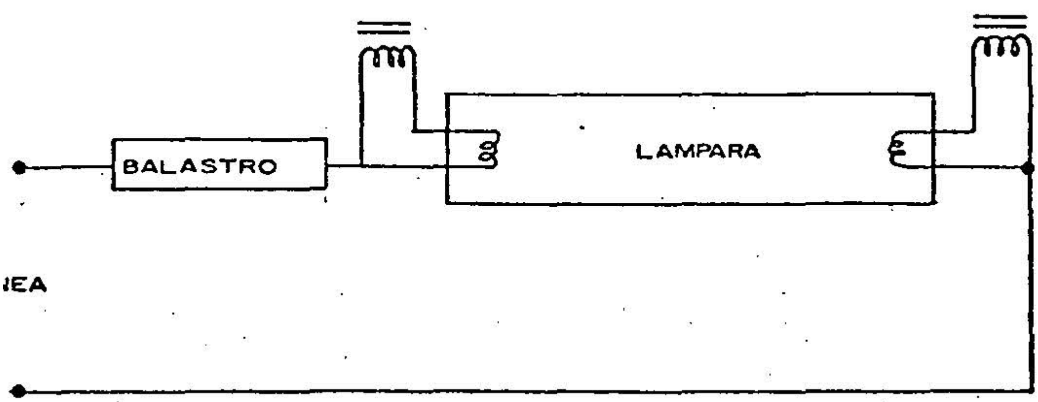


ENCENDIDO PRECALENTADO

n instante después se abre el interruptor térmico (cebador o arrancador) presentándose las dos condiciones necesarias -- para el encendido.

b) Encendido Rápido

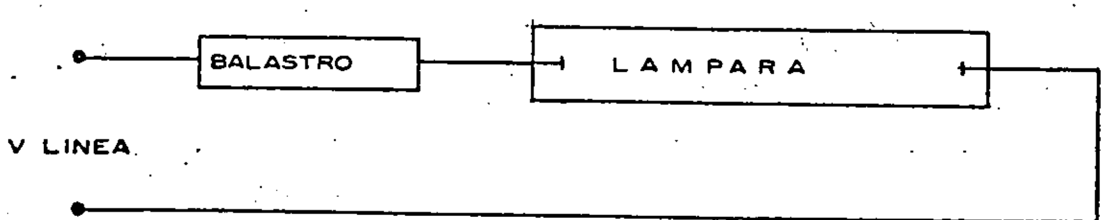
En el encendido rápido, devanados auxiliares proporcionan calentamiento contínuo a los cátodos mediante la aplicación de un voltaje pequeño en los mismos, con lo cual se tiene la nube electrónica disponible, y con la aplicación de un voltaje mayor al mínimo necesario se cumplen las condiciones para el encendido



ENCENDIDO RAPIDO

c) Encendido Instantáneo

En el encendido instantáneo se tienen disponibles los electrones en los cátodos por efecto de campo; ésto es que, para este tipo de encendido se amplía un voltaje en los extremos de la lámpara los suficientemente alto, como para que los electrones del material emisivo de los cátodos sean literalmente arrancados, y empiecen a viajar hacia el cátodo contrario iniciando la descarga eléctrica a través del gas.



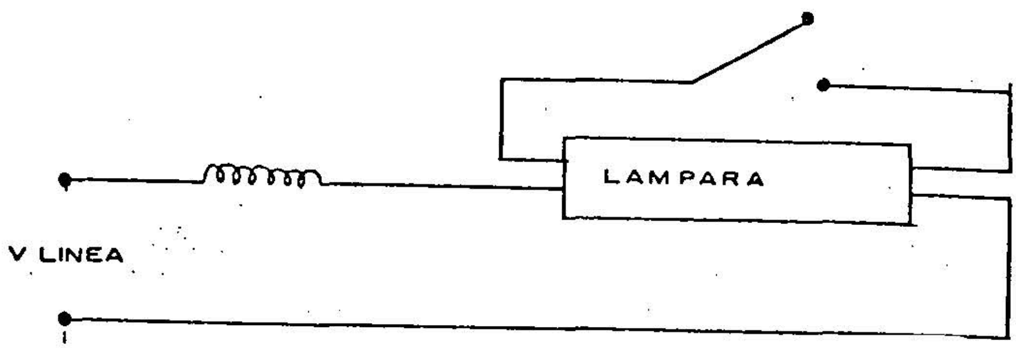
ENCENDIDO INSTANTANEO

Cada tipo de encendido presenta ventajas y desventajas sobre los otros, sin embargo todos tienen campo de aplicación, y por lo mismo mercado.

Ahora por el tipo de circuito que utilizan, los Balastros tienen otra división, a saber:

Principales Circuitos

a) El circuito más sencillo, es la inductancia serie o bobina de choque.

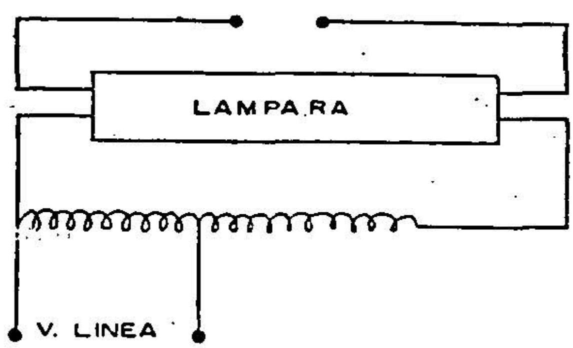


Se usa en líneas de alimentación cuyo voltaje excede el voltaje mínimo de encendido de la lámpara. Para el caso alto factor, se le agrega un capacitor en paralelo con la línea.

Normalmente se usa en encendido precalentado exclusivamente,- aunque se puede utilizar también en encendido instántaneo.

b) Le sigue el circuito autotransformador de alta reactancia, que se usa en los casos en donde el voltaje mínimo de encendido es mayor que el voltaje de línea; usualmente son bajo factor, para alto factor, se utiliza un capacitor -

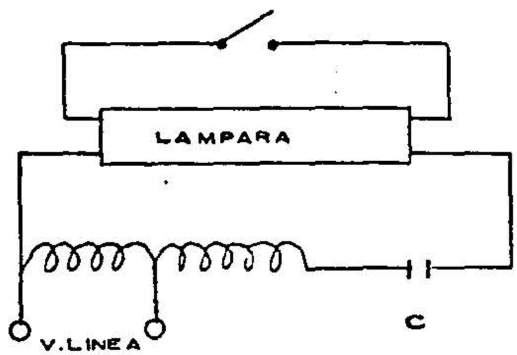
en serie con una inductancia, como se ve en líneas punteadas en el diagrama. Se usa en encendido precalentado, encendido rápido e instantáneo bajo factor de potencia. En este tipo de circuito, la regulación de la corriente de lámpara, se logra mediante la reactancia de dispersión exclusivamente



ALTA REACTANCIA

c) El tercer tipo de circuito es el autotransformador autorregulado; es de alto factor de potencia, y siempre tiene el capacitor en serie con la lámpara. Se usa en todos los balastros de encendido rápido alto factor, y en los de encendido instantáneo alto factor para una sola lámpara.

En este circuito, la combinación de la capacitancia en serie - con la reactancia inductiva de dispersión, proporciona una mejor regulación en la corriente del secundario, que el circuito anterior



BALASTROS H. I. D.

LAS LAMPARAS DE DESCARGA DE ALTA INTENSIDAD (H. I. D.), TAMBIEN SE COMPORTAN COMO LAS LAMPARAS FLUORESCENTES YA QUE PERTENECEN AL MISMO GRUPO DE LAMPARAS DE DESCARGA ELECTRICA EN GAS, POR LO TANTO TAMBIEN ES VALIDO EL RAZONAMIENTO ANTERIORMENTE EXPLICADO SOBRE LA JUSTIFICACION DE LA EXISTENCIA DE BALASTROS H. I. D.

LAS PRINCIPALES LAMPARAS H. I. D. SOBRE CUYOS BALASTROS HABLAREMOS SON :

1.- VAPOR DE MERCURIO
2.- ADITIVOS METALICOS
3.- VAPOR DE SODIO ALTA PRESION
4.- VAPOR DE SODIO BAJA PRESION (*)

(*) SE INCLUYE ESTA LAMPARA, AUNQUE ESTRICTAMENTE HABLANDO NO PERTENECE AL GRUPO H. I. D.

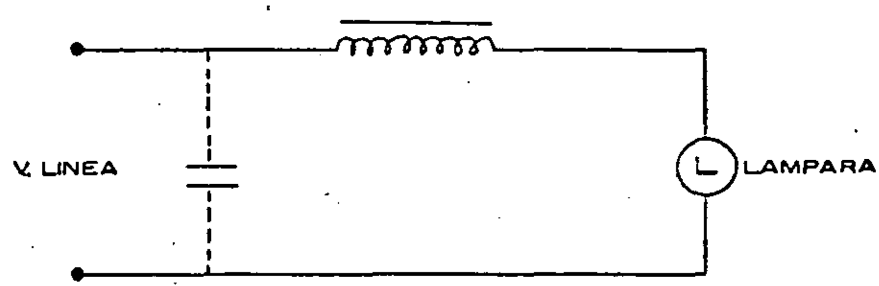
ESTAS LAMPARAS TIENEN COMPORTAMIENTOS DIFERENTES ENTRE SI, Y CON RESPECTO A LAS LAMPARAS FLUORESCENTES, Y UNO DE LOS ASPECTOS DONDE HAY MAYOR DIFERENCIA ES EN EL ARRANQUE.

AUN ASI, SUS BALASTROS TIENEN ASPECTOS EN COMUN, DE TAL MANERA QUE A CONTINUACION DESCRIBIREMOS EN FORMA GENERAL SUS CIRCUITOS :

I.- BALASTROS ATRASADOS :

SU NOMBRE SE DEBE A QUE EN LA FORMA DE ONDA EN LA LAMPARA, LA CORRIENTE VA ATRASADA RESPECTO AL VOLTAJE.

A ESTA CATEGORIA PERTENECEN LAS INDUCTANCIAS SERIE O "BOBINAS DE CHOKE" Y LOS AUTOTRANSFORMADORES DE ALTA REACTANCIA



INDUCTANCIA SERIE

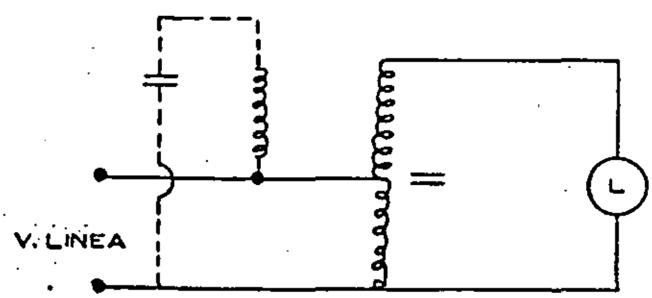
LA INDUCTANCIA SERIE ES EL BALASTRO MAS SENCILLO, Y SE UTILIZA PARA LAMPARAS CUYO VOLTAJE DE ENCENDIDO ES MENOR QUE LA TENSION DE LINEA.

NORMALMENTE ES DE BAJO FACTOR DE POTENCIA, Y SI SE

REQUIERE UN ALTO FACTOR, SE AGREGA UN CAPACITOR EN PARALELO CON LA LINEA.

SU REGULACION DEJA MUCHO QUE DESEAR Y SU CORRIENTE DE ENCENDIDO ES MAYOR QUE LA CORRIENTE NOMINAL DE OPERACION, POR LO QUE DEBE TOMARSE ESTO EN CUENTA PARA EL CALCULO DE LAS PROTECCIONES DE CIRCUITO.

EL VOLTAJE DE EXTINCION (VOLTAJE DE LINEA AL CUAL SE APAGA LA LAMPARA) ES ALTO, PROVOCANDO QUE SE APAGUE LA LAMPARA SI EXISTEN VARIACIONES FUERTES EN LA TENSION DE LINEA.



AUTOTRASFORMADOR ALTA REACTANCIA

EL AUTOTRANSFORMADOR DE ALTA REACTANCIA PERMITE ENCENDER UNA LAMPARA A CUALQUIER TENSION DE LINEA.

SI SE REQUIERE ALTO FACTOR DE POTENCIA, SE LE AGREGA UN CAPACITOR Y UNA INDUCTANCIA EN PARALELO CON LA LINEA COMO SE VE EN LA FIGURA.

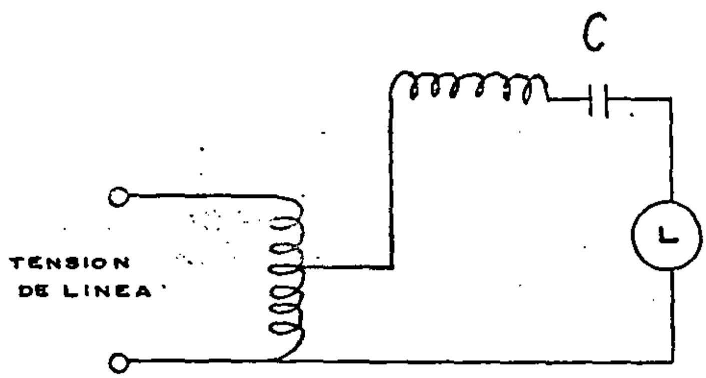
SU REGULACION SIGUE SIENDO MALA COMO LA DE LA INDUCTANCIA SERIE ($\pm$ 5% V LINEA $\pm$ 12% W LAMP.): SU CORRIENTE DE ENCENDIDO ES MENOR QUE LA CORRIENTE NOMINAL DE OPERACION, Y SU VOLTAJE DE EXTINCION TAMBIEN ES ALTO.

EN GENERAL, ES NECESARIO MENCIONAR QUE ESTOS BALASTROS ATRASADOS SON LOS MAS ECONOMICOS Y LOS QUE PROVEEN LAS CARACTERISTICAS DE OPERACION MENOS BUENAS.

II.- AUTOTRANSFORMADORES AUTORREGULADOS

EN EL MERCADO NACIONAL SE LES CONOCE COMO "AUTOTRANSFORMADORES AUTORREGULADOS" Y EN ESTADOS UNIDOS DE NORTEAMERICA SE LES LLAMA AUTOTRANSFORMADORES DE POTENCIA CONSTANTE (C. W. A.).

EL CONTAR CON UNA CAPACITANCIA EN COMBINACION CON UNA INDUCTANCIA PROVEE AL CIRCUITO DE MEJOR CONTROL SOBRE LA OPERACION DE LA LAMPARA.



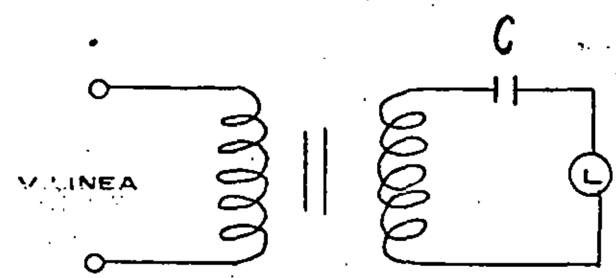
AUTOTRANSFORMADOR
AUTORREGULADO

EN ESTE CIRCUITO, QUE SIEMPRE SERA DE ALTO FACTOR DE POTENCIA, LAS CARACTERISTICAS EN GENERAL SON MEJORES QUE EN LOS CIRCUITOS ATRASADOS; SU REGULACION ES MEJOR ($\pm$ 10% V LINEA $\pm$ 5% W LAMP.), SU CORRIENTE DE ENCENDIDO O ARRANQUE ES MENOR QUE LA CORRIENTE NOMINAL DE OPERACION, Y SU VOLTAJE DE EXTINCION ES MENOR QUE EN LOS CIRCUITOS ATRASADOS.

III.- <u>TRANSFORMADORES DE POTENCIA CONSTANTE</u>

ES EL MEJOR DE LOS BALASTROS, SU PRINCIPAL CÁRACTERISTICA DESDE EL PUNTO DE VISTA CIRCUITO, ES QUE NO EXISTE CONEXION ENTRE EL PRIMARIO Y EL SECUNDARIO AISLADO.

LA VENTAJA QUE SE DERIVA DE ESTA CONDICION ES SEGURIDAD PARA EL USUARIO.



TRANSFORMADOR DE POTENCIA CONSTANTE

POR OTRA PARTE LA REGULACION DE ESTE BALASTRO ES LA MEJOR DEL MERCADO YA QUE PARA UNA VARIACION EN TENSION DE LINEA DE $\pm$ 13% SE OBTIENE UNA VARIACION EN LA POTENCIA DE LAMPARA DE $\pm$ 2%, RAZON POR LA CUAL SE LES HA ASIGNADO EL NOMBRE DE TRANSFORMADORES DE POTENCIA CONSTANTE.

RESPECTO A LA CORRIENTE DE LINEA DURANTE EL ENCENDIDO, ES MENOR QUE LA CORRIENTE NOMINAL DE OPERACION, Y SU VOLTAJE DE EXTINCION ES TAN BAJO, QUE PRACTICAMENTE NO EXISTEN PROBLEMAS DE LAMPARAS APAGADAS POR VARIACIONES SEVERAS EN LA TENSION DE LINEA.

1.- BALASTROS PARA LAMPARAS DE VAPOR DE MERCURIO.-

SUS CIRCUITOS SON EXACTAMENTE LOS DESCRITOS ANTERIORMENTE, ES DECIR :

I.- ATRASADOS

II.- AUTOTRANSFORMADOR AUTORREGULADO

III.- TRANSFORMADOR DE POTENCIA CONSTANTE

2.- BALASTROS PARA LAMPARAS DE ADITIVOS METALICOS.-

LAS LAMPARAS DE ADITIVOS METALICOS REQUIEREN BALASTROS CON CARACTERISTICAS UN POCO DIFERENTES A LOS DE VAPOR DE MERCURIO, PRINCIPALMENTE PORQUE DESPUES DE CIERTO TIEMPO DE HABER ENCENDIDO LA LAMPARA, SE PRESENTA UN ESTADO DE BAJA CONDUCTANCIA EN EL ARCO ELECTRICO QUE EL BALASTRO DEBE SER CAPAZ DE SOPORTAR PROPORCIONANDO MAYOR ENERGIA DE LA NORMAL PARA MANTENER ENCENDIDA LA LAMPARA. ESTE FENOMENO SE CONOCE COMO "REIGNICION"

EL CIRCUITO APROPIADO, DE LOS DESCRITOS ANTERIORMENTE ES EL :

II) AUTOTRANSFORMADOR AUTORREGULADO.

EXISTEN ALGUNAS LAMPARAS DE ADITIVOS METALICOS QUE PUEDEN OPERAR EN ALGUNOS TIPOS DE BALASTROS DE VAPOR DE MERCURIO.

ESTAS LAMPARAS TIENEN UN CIRCUITO DE ARRANQUE ESPECIAL INTEGRADO QUE BASICAMENTE ES UN DOBLADOR DE - VOLTAJE QUE FUNCIONA EN COMBINACION CON EL CAPACITOR DEL BALASTRO, POR LO QUE SOLO PUEDE OPERAR EN BALASTROS DE POTENCIA CONSTANTE O EN AUTOTRANSFORMADORES AUTORREGULADOS.

SIN EMBARGO, ES NECESARIO HACER NOTAR QUE TANTO LA VIDA COMO LOS LUMENS PRODUCIDOS SON MENORES, QUE SI SE UTILIZARA UN BALASTRO DE ADITIVOS METALICOS.

3.- <u>BALASTROS PARA LAMPARAS DE VAPOR DE SODIO ALTA PRESION.-</u>

A DIFERENCIA DE LOS TIPOS ANTERIORES DE LAMPARAS QUE

PARA EL ARRANQUE CUENTAN CON UN ELECTRODO AUXILIAR EN EL TUBO DEL ARCO, LA LAMPARA DE V. S. A. P. POR TENER UN TUBO DEL ARCO MUY DELGADO NO PUEDE ALOJAR ESTE ELECTRODO DE ARRANQUE.

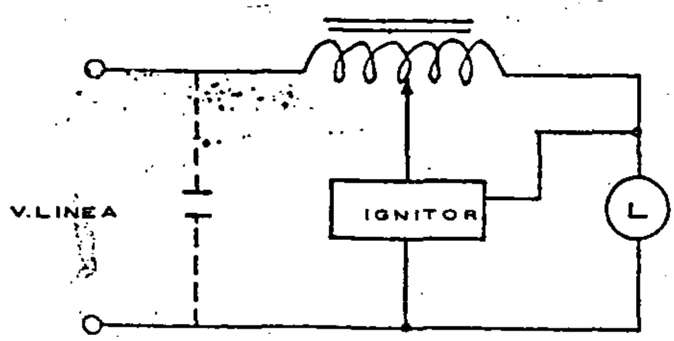
POR ELLO, LOS BALASTROS DE V. S. A. P. CUENTAN CON UN CIRCUITO AUXILIAR QUE GENERA PULSOS DE ARRANQUE DE APROX. 3,500 VOLTS, CON EL UNICO OBJETO DE ENCENDER LA LAMPARA.

ESTE DISPOSITIVO DENOMINADO IGNITOR ESTA CONSTITUIDO DE ELEMENTOS SEMICONDUCTORES, Y ESTA CONECTADO AL CIRCUITO COMO SE VERA EN LAS FIGURAS SIGUIENTES :

LOS CIRCUITOS DISPONIBLES PARA ESTAS LAMPARAS SON APROX. LOS DESCRITOS ANTERIORMENTE CON ALGUNAS VARIACIONES, AUNQUE SU MODO DE OPERACION SEA DIFERENTE.

I) <u>CIRCUITOS ATRASADOS.-</u>

SOLO EXISTE LA INDUCTANCIA SERIE

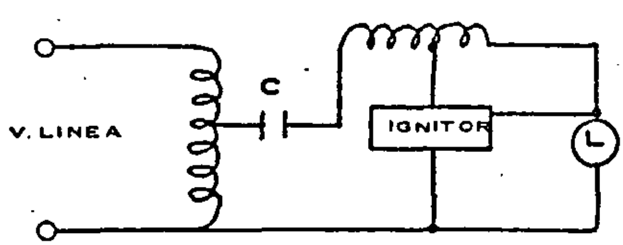


INDUCTANCIA SERIE

II) AUTOTRANSFORMADOR ADELANTADO - REGULADO .-

ES EL EQUIVALENTE DE LOS AUTORREGULADOS PARA LOS 2 TIPOS ANTERIORES DE LAMPARAS.

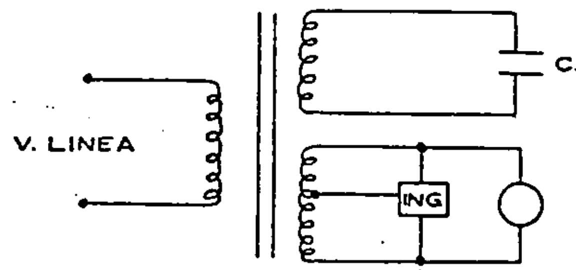
SE LE LLAMA ADELANTADO PORQUE LA CORRIENTE VA ADELANTADA AL VOLTAJE EN LA LAMPARA.



CIRCUITO ADELANTADO - REGULADO

III) CIRCUITO ATRASADO-REGULADO.-

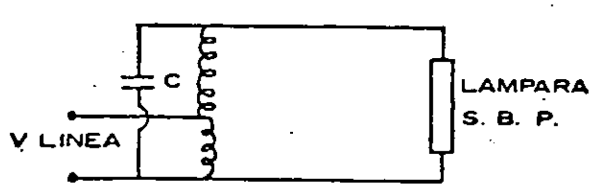
ES EL EQUIVALENTE A LOS CIRCUITOS DE POTENCIA CONSTANTE ANTES DESCRITOS.



CIRCUITO ATRASADO REGULADO

4.- BALASTROS PARA LAMPARAS DE SODIO DE BAJA PRESION.-

POR LAS CARACTERISTICAS PROPIAS DE ESTA LAMPARA, REQUIERE NECESARIA Y UNICAMENTE DE UN BALASTRO TIPO "ATRASADO", POR LO QUE EL UNICO CIRCUITO EXISTENTE A LA FECHA ES EL : AUTOTRANSFORMADOR ALTA REACTANCIA, CON ALTO FACTOR DE POTENCIA.



CIRCUITO ALTA REACTANCIA PARA S.B.P.

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California Energy Commission
Building and Appliance Efficiency Office

Energy-Efficient Fluorescent Ballasts

1993 Advanced Lighting Guidelines March 1993

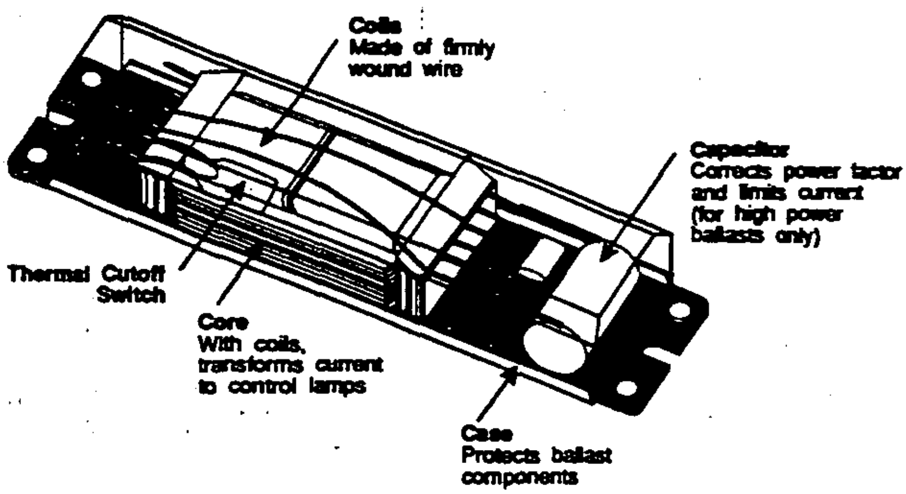

Figure 1
Typical Electromagnetic Fluorescent Ballast

Contents

Introduction

Recent advances in fluorescent lamp ballast technology have created opportunities for improved lamp performance and increased energy efficiency. Relatively new products, such as electronic high-frequency and heater cutout ballasts, are now widely available and accepted in the marketplace. The recent trend toward more competitive pricing of these products should continue, due to an expansion of manufacturing facilities and more competition between manufacturers. Energy-efficient ballasts are an excellent energy-saving strategy that should not be overlooked by anyone who is interested in saving money through the use of efficient lighting products.

The most prevalent fluorescent lamps for general commercial lighting today continue to be the rapid start 4-foot lamp (F40T12) and the instant start, 8-foot, "slimline" (F96T12). However, the more efficacious, smaller diameter F32T8 lamp is gaining in popularity in general lighting applications and as an energy-efficient replacement for standard lamps. This guideline mainly addresses electronic ballasts that operate full-size fluorescent lamps at high frequencies, but it also covers energy-efficient magnetic ballasts with heater-cutout circuits that switch off a lamp's electrode heaters after startup.

Technology Description

All gas discharge lamps, including fluorescent lamps, require a ballast to operate. The ballast provides a high initial voltage to initiate the discharge, then rapidly limits the lamp current to safely sustain the discharge. Lamp manufacturers specify lamp electrical input characteristics (lamp current, starting voltage, current crest factor, etc.) required to achieve rated lamp life and lumen output specifications. Similarly, the American National Standards Institute (ANSI) publishes recommended lamp input specifications for all ANSI type lamps. Ballasts are designed to optimally operate a unique lamp type; however, some ballasts will adequately operate more than one type of lamp. In these cases, optimum lamp performance is generally not achieved under all conditions. Less than optimum conditions may affect the lamp's starting characteristics, light output, and operating life.

Circuit Type and Operating Mode

Fluorescent ballasts are manufactured for three primary types of fluorescent lamps: preheat, rapid start, and instant start.

- *Preheat Operation* Lamp electrodes are heated prior to initiating the discharge. A 'starter switch' closes, permitting a current to flow through each electrode. The starter switch rapidly cools down, opening the switch, and triggering the supply voltage across the arc tube, initiating the discharge. No auxiliary power is applied across the electrodes during operation.
- *Rapid Start Operation* Lamp electrodes are heated prior to and during operation. The ballast transformer has two special secondary windings to provide the proper low voltage to the electrodes.
- *Instant Start Operation* Lamp electrodes are not heated prior to operation. Ballasts for instant start lamps are designed to provide a relatively high starting voltage (with respect to preheat and rapid start lamps) to initiate the discharge across the unheated electrodes.

Rapid start is the most popular mode of operation for 4-foot 40 watt lamps and high output 8-foot lamps. The advantages of rapid start operation include smooth starting, long life, and dimming capabilities. Lamps of less than 30 watts are generally operated in the preheat mode. Lamps operated in this mode are more efficient than the rapid start mode as separate power is not required to continuously heat the electrodes. However, these lamps tend to flicker during starting and have a shorter lamp life. Eight-foot 'slimline' lamps are operated in instant start mode. Instant start operation is more efficient than rapid start, but as in preheat operation, lamp life is shorter. The 4-foot 32 watt F32T8 lamp is a rapid start lamp commonly operated in instant start mode with electronic high-frequency ballasts. In this mode of operation lamp efficacy is improved with some penalty in lamp life.

Energy Efficiency

Fluorescent lamps are reasonably efficient at converting input power to light. Nevertheless, much of the power supplied into a fluorescent lamp-ballast system produces waste heat energy.

There are three primary means of improving the efficiency of a fluorescent lamp-ballast system:

- Reduce the ballast losses.
- Operate the lamp(s) at a high frequency.
- Reduce losses attributable to the lamp electrodes.

Newer, more energy-efficient ballasts, both magnetic and electronic, exploit one or more of these techniques to improve lamp-ballast system *efficacy*, measured in lumens per watt. The losses in magnetic ballasts have been reduced by substituting copper conductors for aluminum and by using higher grade magnetic components. Ballast losses may also be reduced by using a single ballast to drive three or four lamps, instead of only one or two. Careful circuit design increases efficiency of electronic ballasts. In addition, electronic ballasts, which convert the 60 Hz supply frequency to high frequency, operate fluorescent lamps more efficiently than is possible at 60 Hz. Finally, in rapid start circuits, some magnetic ballasts improve efficacy by removing power to the lamp electrodes after starting.

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Figure 2

Ballast Terminology

***Ballast Efficacy Factor (BEF)*:** An efficiency factor defined in ballast regulations (state and federal) that is used to establish minimum efficiency levels for compliance. It equals the percent rated light output (ballast factor times 100%) of a particular lamp-ballast combination under ANSI test conditions divided by the measured input power in watts, (%/ watts). Ballast efficacy factors are significant only for comparing different ballasts operating the same quantity and type of lamp. Current federal and state regulations specify BEF limits for ballasts that operate standard F40T12 and F96T12 lamps.

Ballast Factor: The ratio of a lamp's light output on a ballast, compared to the lamp's rated light output, as measured on a reference ballast. Most ballast factors are less than one; some new ballast designs have ballast factors greater than one.

***Input Voltage*:** The design operating voltage of the ballast. In the U.S., most ballasts are designed to operate at either 120 or 277 volts.

***Lamp-Ballast System Efficacy*:** The ratio of lamp light output to ballast input watts, in units of lumens/watt.

Lamp Current Crest Factor (LCCF): The ratio of the peak current to the root mean square (RMS) lamp current. The LCCF for lamps operated at high frequency is equal to the peak current of the modulated wave (60 Hz) divided by the RMS lamp current. High current crest factors reduce lamp life. The rated lamp life of 20,000 hours for rapid start F40T12 lamps is based on a LCCF of 1.7 or less.

***Line Current Amps*:** The current drawn by the ballast when operating at rated voltage.

***Power Factor*:** The ratio of power (watts) to RMS volt-amps of the ballast. The power factor ratio may be used to determine how efficiently total input power is being used. A High Power Factor (HPF) rating signifies a ballast power factor equal to or greater than 0.90. This HPF rating is most desirable. A Low or Normal Power Factor (NPF) ballast rating signifies a power factor less than .90 – usually between .40 and .70. Utilities may penalize customers whose electric load has a low power factor.

***Regulation* (of line voltage):** The ability of the system light output to adjust for input voltage variations. Generally expressed as a percentage variation in light output of a lamp for a percentage variation in input voltage.

Volt-Amps: The apparent power of a system. It is equal to RMS of voltage times RMS of current.

Ballast Factor

One of the most important ballast parameters for the lighting designer/engineer is the ballast factor. The ballast factor is needed to determine the light output for a particular lamp-ballast system. Ballast factor is a measure of the actual lumen output for a specific lamp-ballast system relative to the rated lumen output measured with a reference ballast under ANSI test conditions (open air at 25 °C [77 °F]). An ANSI ballast for standard 40-watt F40T12 lamps requires a ballast factor of 0.95; the same ballast has a ballast factor of 0.87 for 34-watt energy saving F40T12 lamps. However, many ballasts are available with either high (conforming to the ANSI specifications) or low ballast factors (70% to 75%). It is important to note that the ballast factor value is not simply a characteristic of the ballast, but of the lamp-ballast system. Ballasts that can operate more than one type of lamp (e.g., the 40-watt F40 ballast can operate either 40-watt F40T12, 34-watt F40T12, or 40-watt F40T10 lamps) will generally have a different ballast factor for each combination (e.g., 95%, <95%, and >95%, respectively).

Ballast factor is not a measure of energy efficiency. Although a lower ballast factor reduces lamp lumen output, it also consumes

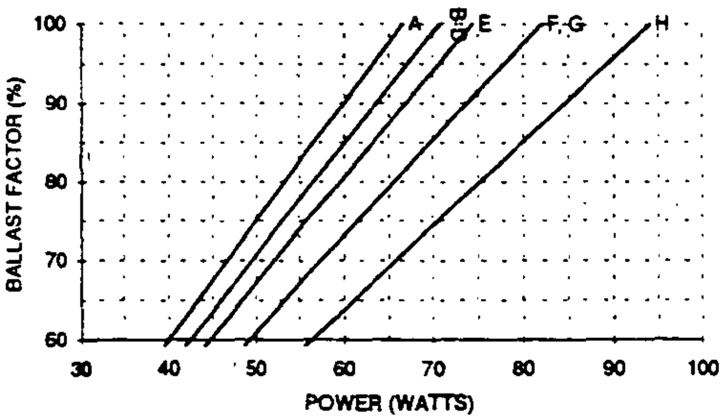
3D

Figure 3

*Power vs. Ballast Factor Curves for Two-lamp Four-Foot Fluorescent Lamp-Ballast Systems**

To use the graph, locate the curve (A-H) for the lamp-ballast system of interest. Draw a vertical line from the cited input power to that curve. Draw a horizontal line from that point to the vertical axis to find the ballast factor for that lamp-ballast system. It is essential that the input power cited by the manufacturer be measured under standard ANSI test conditions.

*Note: This graph is applicable only for two-lamp four-foot systems; other lamp-ballast systems will differ.



A 32W F32T8 IS electronic ballast
B 32W F32T8 RS elect. ballast
C 34W F40T12 RS elect. ballast
D 40W F40T12 RS htr. cut. ballast
E 32W F32T8 RS magnetic ballast
F 40W F40T12 RS elect. ballast
G 34W F40T12 RS mag. ballast
H 40W F40T12 RS mag. ballast

proportionally less input power. As such, careful selection of a lamp-ballast system with a specific ballast factor allows designers to better minimize energy use by "tuning" the lighting levels in the space. For example, in new construction, high ballast factors are generally best, since fewer luminaires will be required to meet the light level requirements. In retrofit applications or in areas with less critical visual tasks, such as aisles and hallways, lower ballast factor ballasts may be more appropriate.

To avoid a drastic reduction in lamp life low ballast factor ballasts (<70%) should operate lamps in rapid start mode only. This is particularly relevant for 32-watt F32T8 lamps operated at high frequency.

Finding the ballast factor for lamp-ballast combinations may not be easy, as few ballast manufacturers provide this information in their catalogs.

However, if the input power for a particular lamp-ballast system is known (usually found in catalogs) an estimate of the ballast factor is possible. Figure 3 provides a set of curves for determining the ballast factor for several two-lamp four-foot lamp-ballast systems. It is based upon the average system efficacy measured for ballasts at standard ANSI conditions.

Lamp-Ballast System Efficacy

The efficiency of a fluorescent lamp ballast changes depending on the type of lamp operated. Similarly, lamp efficacy is affected by ballast technology: the same lamp will perform differently when operated by a heater cutout ballast than it will when operated at high frequency. As a consequence, the only meaningful comparison between lamps or ballasts is the lamp-ballast system efficacy. The system efficacy can be calculated as follows:

$$\text{System Efficacy (lumens / watt)} = \frac{\text{Rated Lamp Lumens}}{\text{Input Power (Watts)}} \times \text{Number of Lamps} \times \text{Ballast Factor}$$

The above equation calculates initial system efficacy as measured under ANSI test conditions. More comprehensive estimates of overall lighting system efficacy can be performed by using data from Figure 3-17 in the *Luminaires and Lighting Systems* guideline, which takes into account luminaire effects on light output and input wattage.

Figure 4 shows how lamp-ballast system performance changes with a simple substitution of ballast. This table is based on two common lamp types: a 34-watt energy saving F40T12/ES and a 32-watt F32T8. Both are RE-70 lamps in which rare earth phosphors are used to produce a color rendering index of between 70 and 79 (See the *Full-Size*

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Figure 4

Comparative Fluorescent Lamp-Ballast Systems

Ballast Type	Typical Input Power (W)	Typical Ballast Factor	System Efficacy (Lumens/Watt)
Two 34 Watt F40T12/RS ES Lamps, 2800 Initial Rated Lumens, RE-70			
Magnetic Energy Efficient	72	0.87	68
Magnetic Heater Cutout	58	0.81	78
Magnetic Heater Cutout—Full Light Output[1]	66	0.88	75
Electronic Ballast A	60	0.85	79
Electronic Ballast B	63	0.82	73
Two 32 Watt F32T8/RS Lamps, 2900 Initial Rated Lumens, RE-70			
Magnetic Energy Efficient	70	0.94	78
Magnetic Heater Cutout	61	0.86	82
Magnetic Heater Cutout—Full Light Output[2]	n.a.	n.a.	n.a.
Electronic Ballast Rapid Start	62	0.88	82
Electronic Ballast Instant Start	63	0.95	87

Notes:
(1) New product at the time of this printing.
(2) New product for which values were unavailable at the time of printing.
All values are as measured under ANSI testing conditions

Fluorescent Lamps guideline for a discussion of lamp phosphors). With electronic ballasts, the input watts are significantly lower. In some cases, the ballast factor is also higher. Figure 8 has more detail on these systems, and includes other systems as well.

Ballast Efficacy Regulations

Beginning in 1982, the State of California began regulating the performance of ballasts operating the most common types of fluorescent lamps. Several other states followed suit, and subsequently, the Federal Appliance Standard prohibited the issue of inefficient ballasts, beginning April 1, 1992. In order to assess ballasts that operated lamps at different light levels the regulations were based upon the Ballast Efficacy Factor (BEF), defined as ballast factor/input power. The regulations set minimum BEF limits for the following type ballasts:

- Two-lamp ballasts for 75-watt F96T12 slimline lamps
- Two-lamp ballasts for 110-watt F96T12 high output lamps
- One-lamp ballasts for F40T12 rapid start lamps
- Two-lamp ballasts operating F40T12 rapid start lamps

BEF criteria are not required for either low temperature or dimming ballasts.

BEF was selected as a measure to allow meaningful comparisons between different ballasts by eliminating lamp variations as a factor. The BEF metric is used solely to show compliance with the state and federal ballast efficacy regulations. *It should not be used as a ballast specification criterion.* The BEF is not a true measure of ballast efficiency as its value depends on the following factors:

- Quantity of lamps operated
- Type of gas fill in the lamp (i.e. argon vs. argon/krypton fill)
- Lamp tube diameter (T-8, T-10, T-12)
- Lamp operating frequency

Some ballast manufacturers provide BEF data in their catalogs, but it is only of value when comparing ballasts operating the same type and number of lamps. In general, BEF values are not particularly useful to the specifier; the best method of comparing lamp-ballast systems is by their system efficacy.

Flicker

Electromagnetic ballasts are designed to condition the 60 Hz input voltage to the electrical requirements of the lamps. A magnetic ballast alters the voltage, but not the frequency. Thus, the lamp voltage crosses zero 120 times each second, resulting in 120 Hz light output oscillations. This results in about 30% flicker for standard halophosphor lamps, operated at 60 Hz. The flicker is generally not noticeable but there is evidence that flicker of this magnitude can cause adverse effects, such as eyestrain and headache.

Most electronic ballasts, on the other hand, use high-frequency operation, which reduces lamp flicker to an essentially imperceptible level. The flicker percentage of a particular ballast is usually specified by the manufacturer. For a given ballast, the percent flicker will be a function of lamp type and phosphor composition.

Audible Noise

One characteristic of iron-cored electromagnetic ballasts operating at 60 Hz, is the generation of audible noise. Noise can be increased by high temperatures, and it is amplified by certain luminaire designs. The best ballasts use high quality materials and workmanship to reduce noise. Noise is rated A, B, C, or D in decreasing order of preference. An "A" rated ballast will hum softly; a "D" rated ballast will make a loud buzz. The number of ballasts, their sound rating, and the nature of ambient noise in the room determine whether or not a system will create an audible disturbance.

Virtually all energy-efficient magnetic ballasts for F40T12 and F32T8 lamps are "A" rated, with a few exceptions, such as low temperature ballasts. Still, the hum of magnetic ballasts may be perceptible in a particularly quiet environment such as a library. Well-designed electronic high-frequency ballasts, on the other hand, should emit no perceptible hum. All electronic ballasts are "A" rated for sound.

Dimming

Unlike incandescent lamps, fluorescent lamps cannot be properly dimmed with a simple wallbox device such as those used for incandescent lamps. For a fluorescent lamp to be dimmed over a full range without a reduction in lamp life, its electrode heater voltages must be maintained while the lamp arc current is reduced. As such, lamps operated in rapid start mode are the only fluorescent lamps suitable for wide-range dimming applications. The power required to keep electrode voltage constant over all dimming conditions means that dimming ballasts will be less efficient when operating lamps at dimmed levels.

Dimming ballasts are available in both magnetic and electronic versions, but there are distinct advantages to using electronic dimming ballasts. To dim lamps, magnetic dimming ballasts require control gear containing expensive high power switching devices that condition the input power delivered to the ballasts. This is economically viable only when controlling large numbers of ballasts on the same branch circuit. In addition, luminaires must be controlled in large zones that are determined by the layout of the electrical distribution system. Since the distribution system is fixed early in the design process, control systems using magnetic dimming ballasts are inflexible and are unable to accommodate changes in usage patterns.

Dimming of electronically-ballasted lamps, on the other hand, is accomplished within the ballast itself. Electronic ballasts alter the output power to the lamps by a low-voltage signal into the output circuit. High power switching devices to condition the input power is not required. This allows control of one or more ballasts independent of the electrical distribution system. With dimming electronic ballast systems, a low voltage control network can be used to group ballasts together into arbitrarily-sized control zones. This control network may be added during a building renovation or even, in some circumstances, during a lighting retrofit. Low voltage wiring does not have to be run in conduit, which helps keep installation costs down. In addition, it is less costly to modify the size and extent of lighting zones by reconfiguring low voltage wiring when usage patterns change. Low voltage wiring is also compatible with photocells, occupant sensors, and energy management system (EMS) inputs.

Dimming range differs greatly among ballasts. With most electronic dimming ballasts, light levels can vary between full output and a minimum of about 10% of full output. However, electronic, full-range dimming ballasts are also available that operate lamps down to 1% of full lumen output. Magnetic dimming ballasts also offer many dimming options, including full-range dimming.

Harmonics

When a current or voltage wave shape deviates from the ideal (sinusoidal), current or voltage harmonics are produced. Harmonics are sinusoidal voltages or currents that are higher multiples of the fundamental frequency. For example the harmonics of 60 Hz are 60 Hz, 120 Hz, 180 Hz, etc., representing the first (fundamental), second, third, etc. multiples. Fluorescent ballasts affect the current, as opposed to the input voltage; in the process, current harmonics are generated. The amplitude of these harmonics are expressed as a percentage of fundamental.

Recently electrical utilities have been concerned with the growing use of electrical equipment that generates harmonics. Such equipment may include variable speed drives, uninterruptable power supplies, personal computers, and electronic ballasts. Any circuit that is nonlinear (e.g. a gas discharge lamp), uses rectifying circuits, or uses high speed switching systems will generate harmonics. If any one or combination of the above systems makes up a significant portion of a building's electrical load, the following undesirable effects may result:

- Overloading of transformers
- Adding of current to the neutral in three phase electrical distribution systems
- Current/voltage surges and/or spikes due to circuit resonances with one or more of the harmonic frequencies
- Interference with electrical equipment or communications on the same circuit
- Distortion of the electrical service entrance voltage with accompanying adverse effects on the performance of other electrical equipment in the building

Harmonic Distortion and Electronic Ballasts

When electronic high-frequency ballasts were first introduced in the early 1980s, some models generated relatively high line harmonics. Nevertheless, at that time, harmonic currents produced by lighting equipment and other electronic systems were not, as yet, a utility issue. However, by the mid-1980s, utilities and power engineers were becoming increasingly more concerned about power equipment that generated line harmonics.

The harmonics issue first surfaced as a concern to the professional lighting community when a major utility announced that electronic ballasts were required to have total harmonic distortion (THD) of less than 20% of the fundamental in order to qualify for their rebate program. Electronic ballast manufacturers responded to the utility's requirement by employing passive filtering that met the 20% limit at a slightly higher cost to the end user.

To help understand the issue, it is of interest to examine and compare the harmonics generated by *magnetic* ballasts. The harmonics for some magnetic ballasts exceed the 20% limit, and have been measured at levels over 37%. This suggests that there are presently many magnetic ballasts in use that exceed the 20% THD limit. These ballasts have not been known to cause any problems with the electrical distribution where they are installed, further suggesting that the choice of a 20% limit on THD may be arbitrarily conservative. In any case, most electronic ballast manufacturers now make electronic ballasts that are well under the 20% limit.

ANSI Harmonic Standards for Electronic Ballasts

The Fluorescent Lamp and Ballast Committees of ANSI are proposing updated harmonics standards for electronic ballasts. These will be consensus standards that consider the harmonic levels found for all ballasts in the field. These figures are summarized in Figure 5. The proposed standards are intended to provide guidance for ballast developers and manufacturers, and they are based on the absence of reported problems associated with existing magnetically-ballasted products. The proposed ANSI standards are slightly more restrictive than existing European harmonic standards (IEC 555).

Third Harmonics of Current Electronic Ballasts

Figure 6 lists test results for the third harmonics (potentially disruptive 180 Hz currents that add upon the three phase neutral) of several electronic ballasts now on the market. There are electronic ballasts that have third harmonic levels below 20% and 10%. Harmonic levels of 20% are achieved by passive filtering devices, such as chokes, resistors and capacitors. Active filters, such as integrated circuits and other semi-conductive devices can reduce harmonics down to well under 10%.

While both electronic and magnetic fluorescent lamp ballast generate harmonics one should understand that it is a systems problem. The potential for adverse effects in a given building primarily depends upon the size of the load imposed by harmonics-generating devices as a proportion of the total building load. The current harmonics (triplens) for fluorescent ballasts in

Figure 5

ANSI Proposed Harmonic Standards for Electronic Ballasts

Fundamental	100%
Second Harmonic (maximum)	5%
Third Harmonic (maximum)	30%
Individual Harmonics >Eleventh	7%
Sum of Odd Triplens[1]	30%
Distortion Factor[2]	32%

(1) Square root of sum of squares of 3rd, 9th, 15th, 21st, etc. harmonics.
(2) Square Root of sum of square of all harmonics (not including the fundamental.

Figure 6

Measured Third Harmonics from 1991 Electronic Ballasts

Ballast	Lamp Type 40W F40T12	32W F32T8	75W F96T12
A	6%	3%	15%
B	29%	23%	34%
C	17%	27%	30%
D	5%	33%	22%

Data collected from unpublished measurements made at the Lighting Research Laboratory at Lawrence Berkeley Laboratories.

three phase distribution systems (e.g., branch circuits) are 120° out of phase and will add on the neutral wire.

Other Harmonics Research

At the present time, data are being collected by the Electric Power Research Institute (EPRI) to measure the voltage distortion at the service entrance of buildings that are lighted with electronically-ballasted fluorescent lamps. While the proposed ANSI standards appear to be adequate at the present time, the data currently being collected should determine whether or not future lighting equipment should require more stringent harmonic limits. The new limits would take into consideration the relative contribution of lighting to the total electrical load in relation to the expanded use of other equipment (personal computers, variable speed drives, microwave equipment, etc.) that also generates line harmonics.

K-Factor and Harmonic Distortion

K-Factor is a metric used for electrical transformer design that accounts for non-sinusoidal currents (i.e. currents that cause harmonics). These line currents generate higher eddy currents than a pure 60 Hz sinusoidal fundamental. Eddy currents cause transformers to operate at higher temperatures, increasing losses. To reduce the effect of eddy currents, transformer manufacturers use secondary windings consisting of well-insulated, multiple wire strands. This increases the resistance of those windings, helping to limit the flow of eddy currents.

Until recently, engineers rarely specified K-factors for transformers. However, it is recommended that electrical engineers designing lighting distribution systems calculate the K-Factor from the known harmonic distortion generated by the lamp-ballast system under consideration. This figure should be available from the ballast manufacturer. ANSI/IEEE 57.110-1986 is the recommended practice for establishing transformer capability for non-sinusoidal line currents, and it contains the equations for calculating K-Factor. Transformers with K-Factors of 1, 4, 9, 13, and 20 are standard products. Transformers with K-Factors of 4 or less are usually sufficient for lighting systems.

Harmonic Distortion and Power Factor

As was noted in Figure 2, utilities are concerned with low power factors because end users draw higher currents for the power that they are using. Ideally, lighting equipment should have a power factor greater than 0.9 and as close to 1.0 as possible. Power factors of less than 1.0 occur when the voltage and current are out of phase and/or when the sinusoidal wave shape is distorted. Harmonic currents generated by electronic ballasts reduce power factor due to a distorted current wave shape. (Harmonic currents produced by other types of electronic equipment can also lower the power factor by producing a phase shift between the voltage and current.)

Electronic ballast manufacturers now make a habit of publishing the percentage of total harmonic distortion (THD) produced by their products. This allows a lighting professional to quantify how the installation of electronic ballasts in a building will affect power factor. Electrical distribution wiring may be sized accordingly. The relationship between power factor and total harmonic distortion with no voltage-current phase shift may be determined as follows:

$$\text{Power Factor} = \sqrt{\frac{1}{1+\text{THD}^2}}$$

As long as there is no voltage-current phase shift contribution to the power factor, THD may be as high as 48% and maintain a power factor of over 0.90.

Reliability of Electronic Ballasts

The reliability of electronic ballasts has been questioned since their introduction in 1981. Some manufacturers' initial products failed prematurely. Those manufacturers who were unable to improve their products are no longer producing electronic ballasts. Other manufacturers have been in production over ten years with documented ballast failure rates of less than 1% after five years of operation. At this time, it is apparent that long term usage has demonstrated the reliability of electronic ballasts.

A main reason for the questioning of the reliability of electronic ballasts has been the lack of large scale, controlled, on-site data. However, in 1988, the University of California-Berkeley energy management group presented their findings on failures of electronic ballasts installed in a variety of campus buildings over a period of three and one-half years. Over 32,000 electronic ballasts were installed, supplied by three different manufacturers. (Source: R.S. Abesamis, et.al., "Field Experience with High-Frequency Ballasts", Trans. IEEE-IAS, 26, #5, 810, Sept./Oct. 1990.) Two of the manufacturers' ballasts had failure rates of less than 1% – well within acceptable limits. The third manufacturer's ballasts had a 6% failure rate, and the company has since ceased manufacturing electronic ballasts. For comparison purposes, the general failure rate for 60 Hz magnetic ballasts is about 0.5%.

The results of the University of California case study clearly demonstrate that electronic ballast technology has advanced enough so that efficient, reliable electronic ballasts can be successfully designed and manufactured in large volume. Based on these findings, the University's ballast retrofit program was expanded, and a total of over 75,000 electronic ballasts have been installed at the campus, leading to considerable energy savings.

The above case study suggests that reliable electronic high-frequency ballasts can be produced with the quality control necessary to reach or exceed the ten to twelve year life span common with magnetic ballasts. Most ballast failures, when they do occur, will happen within the first six months of installation. Early ballast failures are usually due to either poor quality control in the manufacturing process or to incorrect installation procedures. Failures occurring after a normal "wear-out" period of ten to twelve years are usually due to the eventual degradation of the electrolytic capacitor.

Electronic ballast problems can be kept to a minimum if specifiers are diligent in their selection of ballast manufacturers. They should research the track records of manufacturers and obtain verification for the reliability of any new or unfamiliar products.

Current Products

There are two methods of improving the efficacy of fluorescent lamp-ballast systems. One involves a simple modification to the magnetic energy-efficient ballast; the other utilizes electronics to operate fluorescent lamps at a high frequency.

Heater Cutout (Hybrid) Ballasts

Heater or electrode cutout energy-efficient magnetic ballasts are equipped with an electronic circuit that removes the voltage to the electrode heaters in rapid start fluorescent lamps once the lamps are ignited and operating. (These are sometimes called "hybrid" ballasts, due to the electronic cutout circuit. They should not be confused with electronic ballasts that operate lamps at high frequency.) Most heater cutout ballasts consume about 16 fewer watts of input power (two-lamp 40-watt F40 system) than standard magnetic energy-efficient ballasts, but lumen output is reduced by around 12%. However, one manufacturer now offers a product that produces the same lumen output as does a magnetic energy-efficient ballast while operating at six fewer watts in a two-lamp F40 system.

Heater cutout ballasts are cost effective and energy efficient and will operate most straight tube rapid start F40 lamps. In addition a full light output heater cutout ballast for F32T8 lamps is now available. Heater cutout ballasts should only be used with rapid start lamps, and they should not be used in dimming applications. Some lamp manufacturers derate lamp life by 25% for heater cutout operation.

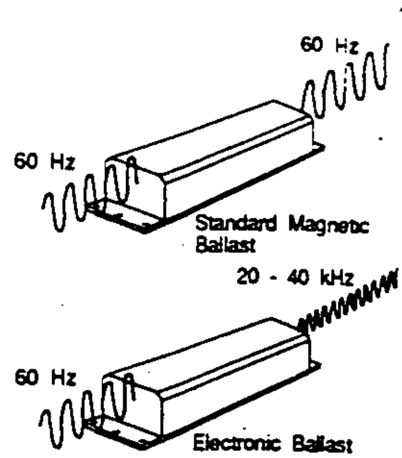

Figure 7
Magnetic & Electronic Ballasts

Electronic Ballasts

Electronic high-frequency ballasts increase lamp-ballast efficacy, leading to increased energy efficiency and lower operating costs. Electronic ballasts operate lamps using electronic switching power supply circuits. Electronic ballasts take incoming 60 Hz power (120 or 277 volts) and convert it to high-frequency AC (usually 20 to 40 kHz). Electronic ballasts are more efficient than magnetic ballasts in converting input power to the proper lamp power, and their operating of fluorescent lamps at higher frequencies reduces end losses, resulting in an overall lamp-ballast system efficacy increase of 15% to 20%.

Electronic ballasts have a number of other advantages over magnetic ballasts. Electronic ballasts are readily available that operate three or four lamps, allowing the use of a single ballast in three-lamp and four-lamp luminaires. This reduces both installation and field wiring labor costs, and may negate the necessity of tandem luminaire wiring as required by the 1992 *Energy Efficiency Standards for*

Residential and Nonresidential Buildings (Title 24). Electronic ballasts are designed to operate lamps in either series or parallel mode. The advantage of the parallel mode of operation is that a single lamp failure will not affect the operation of the remaining lamps controlled by the same ballast. However, ballast losses will increase slightly in the parallel mode. Other advantages of the electronic ballast include reduced weight, quieter operation, and reduced lamp flicker. Electronic ballasts are directly interchangeable with magnetic ballasts, and they are available to operate most full-size and compact fluorescent lamps. Electronic ballasts currently available include the following principal types. In most cases more than one manufacturer offers a product, and all types listed here are available at this time.

Rapid Start Electronic Ballasts

Rapid start electronic ballasts heat lamp electrodes continually during starting and operation. Ballasts are available for one, two, three, and four-lamp operation. Some ballasts will operate either T-8, T-10, or T-12 lamps. However, the ballast factor will not be constant for all lamp types, and lamp operation may not be in accordance with the lamp manufacturer's recommendations.

Instant Start Electronic Ballasts

Instant start electronic ballasts are available for the popular 75-watt F96T12 slimline lamps commonly used in many commercial applications. Ballasts are available for either one or two lamps. Instant start ballasts that operate rapid start T-8 lamps at full light output are also available. Although these lamps are rapid start, the lamp electrodes are never heated. This increases system efficacy. Lamp life is reduced by approximately 25% (for 20,000 hour lamps at three hours per start), but this is compensated for by increased energy efficiency. In most commercial applications, where lamps are operated at ten hours per start or longer, lamp life is only slightly reduced in comparison to rapid start operation.

Using occupant sensors with instant start lamp-ballast systems may cause an accelerated loss of lamp life for rapid cycle times. Rapid start lamp operation is usually a better choice in such applications.

Two-Level Electronic Ballasts

Two-level electronic ballasts increase the flexibility of standard electronic ballasts by allowing the light level to be switched between 50% and 100% of full light output. These ballasts may be used to meet the bi-level switching requirements in Title 24. Standard switches, occupant sensors, photocells, or other building energy management control devices may be used to switch the ballast. A two-level ballast is supplied with an additional input lead to allow the switching between 50% and 100% operation.

Adjustable Output (Dimming) Electronic Ballasts

Dimming electronic ballasts permit the light output of the lamp to be continuously controlled over a range of approximately 10% to 100% of full light output. A low voltage signal (usually between 0 and 10 volts) to the ballast output circuit modifies the current to the lamp. Dimming electronic ballasts are equipped with feedback circuits that maintain electrode voltage when the lamp current is reduced. This allows the lamp to be dimmed over a wide range without reducing lamp life. This dimming technique contrasts with that of magnetic ballasts in which input power to the ballast is modified to alter the lamp current, which also reduces electrode voltage. This limits the practical dimming range of lamp to about 50% of full light output.

Full Range Dimming Ballasts

A full dimming range of from 1% to 100% of full light output may be achieved through the use of premium-priced electronic ballasts designed for this purpose. At present, these ballasts are part of proprietary control systems.

Performance of Advanced Products

Typical performance characteristics of several energy-efficient lamp-ballast systems are illustrated in Figure 8. Of particular interest is the variation in the performance of ballasts operating the same types of lamps. This demonstrates the wide range of ballast choices available to lighting practitioners, allowing them to attain their lighting objectives more efficiently.

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Figure 8

Typical Performance Values for Lamp-Ballast Systems (Two-Lamp Systems)

Ballast Types	Lamp Watts (ea.)	Input Watts	Initial Lamp Lumens	Ballast Factor	System Efficacy
Pre-1990 ANSI/CBM Magnetic					
2-F40T12/RE70	40	96	3200	0.94	62
2-F40T12/ES/RE70	34	82	2800	0.87	59
Standard Energy-Efficient Magnetic					
2-F40T12/RE70	40	88	3200	0.94	68
2-F40T12/ES/RE70	34	72	2800	0.87	68
2-F40T10/RE80	42	92	3700	0.95	76
2-F32T8/RE70	32	70	2900	0.94	78
2-FT40W/2G11 (RE80)	40	86	3150	0.93	68
2-F96T12 Slimline/RE70	75	158	6425	0.94	76
2-F96T12HO/RE70	110	237	9200	0.94	73
Magnetic Heater Cutout					
2-F40T12/RE70	40	69	3200	0.83	77
2-F40T12/ES/RE70	34	58	2800	0.81	78
2-F40T10/RE80	42	74	3700	0.85	85
2-F32T8/RE70	32	61	2900	0.86	82
Full Light Output Magnetic Heater Cutout (New Product)					
2-F4012/RE70	40	80	3200	0.95	76
2-F40T12/ES/RE70	34	66	2800	0.88	75
Electronic Rapid Start					
2-F40T12/RE70	40	72	3200	0.88	78
2-F40T12/ES/RE70	34	62	2800	0.88	79
2-F40T10/RE80	42	74	3700	0.85	85
2-F32T8/RE70	32	62	2900	0.88	82
2-FT40W/2G11 (RE80)	40	71	3150	0.83	74
2-F96 HO/RE70	110	190	9200	0.81	78
Electronic 75% Reduced Output Rapid Start					
2-F40T12/RE70	40	61	3200	0.73	77
2-F40T12/ES/RE80	34	52	2800	0.73	79
2-F40T10/RE80	42	63	3700	0.73	86
2-F32T8/RE70	32	51	2900	0.71	81
2-FT40W/2G11 (RE80)	40	60	3150	0.70	74
Electronic Instant Start					
2-F32T8/RE70	32	63	2900	0.95	87
2-F96T12 Slimline/RE70	75	130	6425	0.84	83
Electronic Two-Level Rapid Start (50% and 100% of Full Light Output)					
2-F40T12/RE70	40	37/69	3200	0.40/0.86	69/80
2-F40T10/RE80	42	40/72	3700	0.40/0.86	74/88
2-F32T8/RE70	32	38/65	2900	0.50/0.94	76/84

Application Guidelines

Advanced technology ballasts improve the efficacy of fluorescent lamp systems and are appropriate for both new construction and retrofit applications.

Electronic Ballasts

Electronic ballasts for fluorescent lamps can save energy and dollars in nearly every application. There is a cost premium for electronic ballasts, which may be reduced by utility rebate programs, but prices are becoming more competitive as the market expands. Users like the University of California have demonstrated that electronic ballasts are an excellent institutional investment. Electronic ballasts may be substituted for magnetic ballasts without any need for concern about lighting system performance. In fact, electronic ballasts can enhance lighting quality through the added benefit of a quiet, flicker-free lighting environment. This makes electronic ballasts an ideal choice for modern offices and in other applications with important visual tasks.

Use the following criteria when making ballast selections:

- Always consider electronic ballasts for general purpose applications in new construction. The higher cost of electronic ballasts makes economic sense in terms of energy savings and improved lighting performance.
- Always consider electronic ballasts for routine maintenance replacements and renovations. (It may not be cost-effective to retrofit large groups of existing energy-efficient magnetic ballasts in working order that

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Figure 8 (continued)

Typical Performance Values for Lamp-Ballast Systems (Two-Lamp Systems)

Ballast Types	Lamp Watts (ea.)	Input Watts	Initial Lamp Lumens	Ballast Factor	System Efficacy
Electronic Adjustable Output (to 15%)					
2-F40T12/RE70	40	73	3200	0.89	78
2-F40T12/ES/RE70	34	60	2800	0.86	80
2-F40T10/RE80	42	73	3700	0.87	88
2-F32T8/RE70	32	73	2900	1.04	83
Electronic Dimming (to 1%)					
2-F40T12/RE70	40	83	3200	0.93	72
2-F40T10/RE80	42	85	3700	0.93	81
2-F32T8/RE70	32	75	2900	1.00	77
2-FT40W/2G11 (RE80)	40	80	3150	1.00	79

*Notes:
All values as measured under ANSI test conditions (25 °C [77 °F] open air).
75% reduced output refers to percentage of rated lamp lumen output that this lamp is deliberately designed to produce (also referred to in text as a "low ballast factor" ballast)
All lamps except F40T10s and FT40 twin tubes are RE-70 phosphor coatings; T-10s and FT40s are RE-80 phosphor coatings.
All values for input watts and ballast factors are for specific ballasts available on the market. Other ballasts may differ substantially from these values.

would not otherwise be replaced.)

- Consider operating F32T8 lamps at full output with instant start ballasts to obtain maximum energy efficiency for dedicated (non-dimming) applications.
- Exercise caution to avoid using instant start lamp-ballast systems with occupant sensors or other applications with rapid switching cycles.
- Consider stepped multi-level electronic ballasts as an excellent alternative to switching adjacent lamps in luminaires (tandem wiring) to meet Title 24 requirements. An additional benefit will be a quiet, flicker-free, space.
- Consider the use of low ballast factor (<75%) rapid start electronic ballasts in aisles or other circulation areas where partial light output will suffice. Installation of low ballast factor ballasts is also a cost-effective solution for retrofitting spaces that are over-illuminated. Low ballast factor electronic ballasts should be operated in rapid start mode only to maintain lamp life at reduced lamp currents.
- Consider full range (1% to 100%) dimming electronic ballasts for functional dimming requirements in applications such as board rooms, conference rooms, and residences.

Continuously adjustable dimming electronic ballasts are especially appropriate for all of the following lighting control strategies (see the appropriate guidelines for application details):

- *Tuning*: the adjustment of illuminance levels according to user needs
- *Daylighting*: the control of electric lighting levels in spaces where natural light is present
- *Lumen maintenance*: the reduction of lighting power lost in conventional systems that are designed to produce excess light when new to compensate for future light depreciation
- *Peak demand limiting* (load shedding): the reduction of lighting power during the time of day when utility charges are at their highest levels
- *Adaptation compensation*: adjusting interior lighting levels to more closely correspond with exterior illumination

In most instances, electronic ballasts are manufactured in standard ballast housings. This allows for quick and easy replacement in existing luminaires and permits their use in already tooled new luminaires. To facilitate replacement, the wires on typical non-dimming electronic ballasts use the same color coding as magnetic ballasts. Installation of electronic ballasts is actually easier than installing magnetic ballasts, because they weigh less. Most adjustable output and dimming ballasts have separate, low-voltage leads that permit a low voltage, Class I signal to control lamp output. These ballasts are often designed to use some form of optical isolator mounted in the luminaire so that Class II low voltage wiring can be used within the building. Other dimming ballasts require no additional control wiring.

System Compatibility of Electronic Ballasts

Like virtually all lighting products, there are some applications in which high-frequency electronic ballasts may be incompatible with existing technologies. One of these instances that has been identified occurs in libraries equipped with magnetic detectors used to prevent theft. However, as long as electronic ballasts are at least 10 to 15 feet away from the detector units, problems with the detectors are unlikely to occur.

A second potential system compatibility problem with electronic ballasts may occur in conjunction with high frequency power line carrier (PLC) control systems. The carrier frequency for PLCs usually ranges from 50 kHz to 200 kHz. These frequencies may be affected by one of the harmonic currents generated by electronic ballasts. The extent of this potential problem has not as yet been fully researched. However, in simple PLC systems for residential applications when lighting and other appliances share the same distribution network, electronic ballasts may not be compatible. This may be resolved by the selection of a more appropriate frequency for the PLC system. In commercial systems where the PLC is isolated from the lighting circuits, problems may be minimal. If, however, the PLC is used to control the lighting system, the probability of problems occurring will increase.

It is important to realize that the possible compatibility problems posed by the use of electronic ballasts arise only on rare occasions. The above incompatibilities can be resolved or avoided, and they should not be used to disqualify the use of electronic ballasts in other applications.

Heater Cutout Ballasts

Heater cutout ballasts are less expensive than electronic ballasts and are a viable energy-efficient option to consider when a project budget does not permit electronic ballasts. Heater cutout ballasts can be used in any non-dimming situation involving straight 40-watt F40T12 and F40T10 lamps, and a heater cutout ballast for F32T8 lamps is now available. Typical applications include offices, schools, retail and wholesale stores, health care facilities, and general industrial and commercial lighting. Because of their lower initial cost they are especially appropriate for use as replacement ballasts in retrofit applications. Some heater cutout ballasts may have a problem starting very high voltage F40T10 lamps when the line voltage is below the rated center voltage (120/277V). In addition, some lamp manufacturers derate lamp life when lamps are operated by heater cutout ballasts.

Guideline Specifications

The following ballast specifications may be used as a guideline for full-size fluorescent lamp ballasts. In general, for important applications, detailed specifications should be included for ballasts. The specification may include acceptable manufacturers and model numbers, especially when using electronic ballasts.

Electronic Ballasts

1. UL Listed Class P.
2. Sound Rated A.
3. Total harmonic distortion ≤ 32% (<20% for rebates) with input current third harmonic not to exceed ANSI recommendation.
4. Ballast shall conform to ANSI specification C. 82,11-19XX
5. Power factor ≥ 0.90.
6. Enclosure size and wiring in same color as magnetic ballast (for retrofit applications).
7. Ballast factor of ____ (see chart or manufacturer's literature, or as required).
8. Light regulation ±10% with ±10% input voltage variation.
9. Lamp current crest factor ≤ 1.7.
10. Flicker 10% or less with any lamp suitable for the ballast.
11. Lamps shall be operated in (instant start) (rapid start) (rapid start, stepped output) (rapid start, continuously adjustable output) mode.
12. Shall be designed to withstand line transients, per IEEE 587, category A.
13. Shall meet FCC Rules and Regulations, Part 18C.
14. Circuit diagrams and lamp-ballast connections shall be displayed on all ballast packages.
15. Three year warranty including $10 labor allowance.

Heater Cutout Ballasts

1. UL listed class P.
2. Sound rated A.
3. Energy-efficient ballast with heater cutout circuit shall not require restrike period.
4. Standard ballast enclosure size and wiring.
5. Light regulation ±10% with ±10% input voltage variation.
7. Power factor ≥ 0.90.
8. Lamp current crest factor ≤1.7.

9. Shall be designed to withstand line transients, per IEEE 587, category A

Special Note

Specifiers should investigate the marketplace and compare the product offerings with the information contained in this guideline. New product developments may make some portions of this report incomplete or obsolete.

Manufacturer/Product References

Electronic Ballasts	Dimming Electronic Ballasts	Heater Cutout Ballasts
Advance Transformer Co.	Advance Transformer Co.	Advance Transformer Co.
MagneTek Triad	Electronic Ballast Technology, Inc.	MagneTek Universal
ELBA (Light Energy Corp.)	ETTA Industries, Inc.	Valmont Electric
Electronic Ballast Technology	Lutron Electronics	
ETTA Industries, Inc.		
Motorola Lighting, Inc.		
OSRAM Corporation.		
Smallwood P C/Sci.		
Toshiba Electronics		
Valmont Electric		

(Inclusion in this list does not imply applicability or endorsement by the California Energy Commission, the U.S. Department of Energy, or the Electric Power Research Institute. Additional companies may also manufacture these products.)

FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

T E M A 5

F O T O M E T R I A.

NOTAS PREPARADAS POR EL ING. JAVIER ROMERO

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INFORMACION FOTOMETRICA

- Curva Fotométrica.

  Esta contiene toda la información necesaria, en la cual se determina la operación del luminario, así como los coeficientes de utilización.

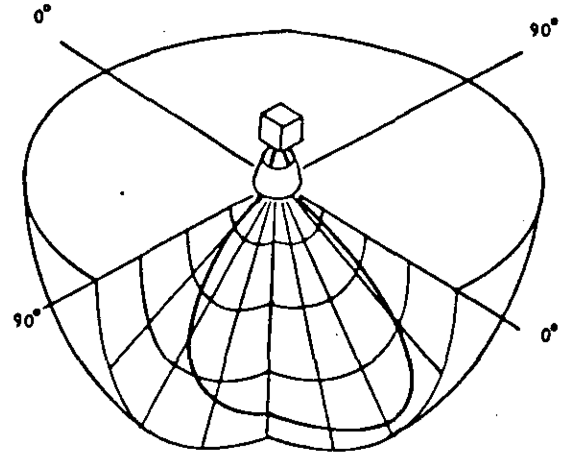
- Distribución de Candelas.

  El nivel de iluminación es obtenida a través de un fotómetro que mide candelas, de 0° - 180° a una distancia de prueba de 7 metros. El luminario se mueve sobre ejes con el objeto de obtener la lectura de la candela promedio en todos los planos del luminario.

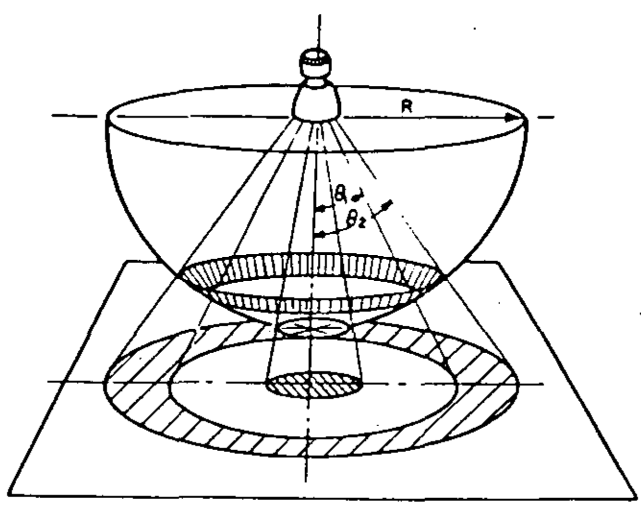
  Las lecturas en candelas de luminario son trazadas sobre una gráfica polar, refiriéndolas al nadir o línea recta hacia abajo. Partiendo de esta información, los lumens de salida del luminario son calculados, así como el coeficiente de utilización (CU), el criterio de espaciamiento(S/MH), y el promedio de brillantez del luminario.

- Información de Distribución.

  La información de la distribución es también proporcionada en forma tabular en la hoja de información fotométrica. El proporcionar la distribución de la candela promedio permite calcular el flujo luminoso en cualquier ángulo del nadir (0°) a 180°, es proporcionada generalmente en zonas de 10°, si bien es mejor utilizar pequeñas zonas donde las candelas cambien rápidamente. La suma de todos los lumens en la zona de 0° a 180° es el flujo luminoso total de salida del luminario.



Cuando la distribución de candela es asimétrica, se pueden trazar curvas para dos o más planos verticales. Si la distribución es elíptica, las curvas tienen una separación de 90 grados, como se muestra en el dibujo.



Los datos de distribución dividen la distribución vertical de una luminaria en zonas de 5 grados. Este dibujo muestra la manera como se ven estas zonas cuando se proyectan sobre el plano de trabajo.

INTERPRETACION DE UNA CURVA EN CANDELAS

DEFINICION.- Una curva polar representa la variación de la intensidad luminosa de un luminario o lámpara en un plano a través del centro de luz. La unidad de medición es la candela.

USOS.- Puede utilizarse en el método de punto por punto, para determinar la iluminación en un punto específico abajo del luminario.

$$\text{Footcandles} = \frac{\text{Candela (cd)}}{\text{Distancia}^2 (D^2)}$$

También puede ser utilizada para determinar la eficiencia.

$$\frac{\text{Total lumens}}{\text{Lumens de lámpara}} = \text{Eficiencia \%}$$

Ejemplo: De la curva del luminario de 400W, VSAP.
- Para calcular la eficiencia del luminario

$$\frac{\text{Total Lumens}}{\text{Lumens de lámpara}} = \frac{38{,}438}{50{,}000} = 76{,}876 = 76.9\%$$

- Lecturas en la curva:

0° (directamente en el nadir) leemos aprox. 15,600
45° aproximadamente 12,000

- Cálculo en Footcandles:

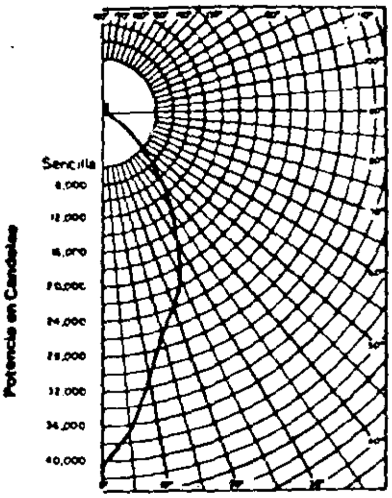
20' directamente abajo del luminario (nadir)

$$\frac{15{,}600}{20^2} = 39 \text{ Fc} = 39 \times 10.76 = 419.25 \text{ luxes}$$

....W. Vapor de Sodio Alta Presión Datos Fo

Unidad Sencilla

Tipo de Lámpara: Vapor de Sodio Alta Presión
Lumens de la Lámpara: 50 000 / lamp
Probado de acuerdo con los procedimientos de la I.E.S.



Haz Cerrado

Balastro No 0500095
Reflector No 0500010-1

Angulo Zona Medio	Potencia en Candelas	Lumens de Zonas: Zona	Lumens
0	40865	0-10	3525
5	37102	10-20	7584
15	26704	20-30	10022
25	21646	30-40	8613
35	13718	40-50	5574
45	7202	50-60	3520
55	3925	60-70	380
65	382	70-80	89
75	84	80-90	24
85	21	90-100	13
90	12	100-110	13
95	12	110-120	12
105	12	120-130	23
115	12	130-140	58
125	25	140-150	559
135	75	150-160	232
145	890	160-170	11
155	502	170-180	3
165	36	Total	40256
175	36		

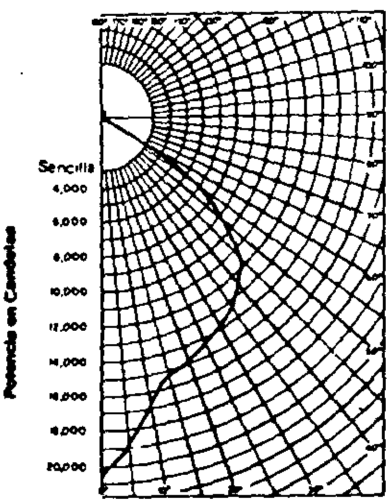
Tabulación Zonal

Grados de Zona	Lumens	% Total de Lumens de la Lámpara
0-30	21131	42.3
0-60	38838	77.7
0-90	39331	78.7
90-180	924	1.8
0-180	40256	80.5

Promedio de Brillantez en Foot-Lamberts

Angulo Vertical	Foot-Lamberts
65°	1179
70°	863
75°	426
80°	313
85°	320

Para unidades cerradas usar el multiplicador .89
Espaciamiento máximo entre luminarios relación 1:0.7 altura de montaje



Haz Medio

Balastro No. 0500095
Reflector No. 0500010-13

Angulo Zona Medio	Potencia en Candelas	Lumens de Zonas: Zona	Lumens
0	20635	0-10	1795
5	18896	10-20	4366
15	15375	20-30	6632
25	14325	30-40	8468
35	13485	40-50	9144
45	11814	50-60	6206
55	6918	60-70	1449
65	1460	70-80	378
75	358	80-90	70
85	84	90-100	16
90	15	100-110	16
95	15	110-120	15
105	15	120-130	15
115	15	130-140	20
125	16	140-150	239
135	26	150-160	176
145	381	160-170	8
155	381	170-180	2
165	28	Total	39015
175	28		

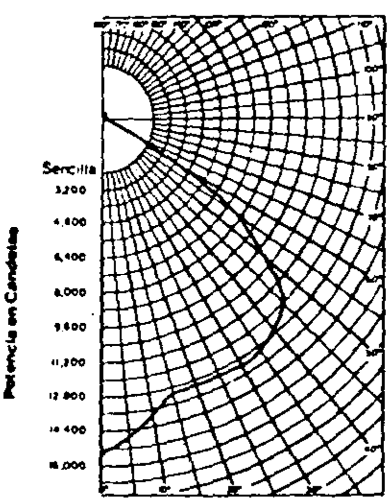
Tabulación Zonal

Grados de Zona	Lumens	% Total de Lumens de la Lámpara
0-30	12793	25.6
0-60	36611	73.2
0-90	38508	77.1
90-180	507	1.0
0-180	39015	78.1

Promedio de Brillantez en Foot-Lamberts

Angulo Vertical	Foot-Lamberts
65°	6132
70°	3803
75°	2458
80°	1705
85°	1307

Para unidades cerradas usar el multiplicador .89
Espaciamiento máximo entre luminarios relación 1:1 altura de montaje



Haz Abierto

Balastro No.0500095
Reflector No.0500010-6

Angulo Zona Medio	Potencia en Candela	Lumens de Zonas: Zona	Lumens
0	15618	0-10	1391
5	14646	10-20	3734
15	13150	20-30	6088
25	13150	30-40	8257
35	13150	40-50	9395
45	12138	50-60	6969
55	7768	60-70	1728
65	1740	70-80	432
75	408	80-90	80
85	73	90-100	16
90	15	100-110	16
95	15	110-120	15
105	15	120-130	15
115	15	130-140	17
125	16	140-150	129
135	23	150-160	146
145	206	160-170	8
155	315	170-180	2
165	27	Total	38438
175	25		

Tabulación Zonal

Grados de Zona	Lumens	% Total de Lumens de la Lámpara
0-30	11213	22.4
0-60	35834	71.7
0-90	38074	76.2
90-180	364	0.7
0-180	38438	76.9

Promedio de Brillantez en Foot-Lamberts

Angulo Vertical	Foot-Lamberts
65°	7312
70°	4518
75°	2802
80°	1074
85°	1479

Para unidades cerradas usar el multiplicador .91
Espaciamiento máximo entre luminarios relación 1:1.3 altura de montaje.

Coeficiente de Utilización / Reflectancia Efectiva de Cavidad de Piso 20% (ρ FC)

% Reflectancia Efectiva Techo (ρcc)	Pared (ρw)	Radio de Cavidad de Cuarto 1	2	3	4	5	6	7	8	9	10
	50	.885	.821	.761	.711	.661	.615	.569	.530	.493	.460
80	30	.863	.768	.721	.665	.611	.564	.519	.480	.443	.410
	10	.845	.760	.689	.630	.575	.530	.484	.444	.407	.378
	50	.866	.806	.750	.701	.650	.607	.563	.524	.488	.456
70	30	.846	.775	.712	.659	.608	.560	.514	.476	.440	.409
	10	.829	.752	.683	.625	.571	.525	.480	.442	.407	.376
	50	.828	.778	.727	.680	.634	.592	.550	.513	.479	.448
50	30	.813	.752	.695	.644	.596	.552	.506	.470	.434	.404
	10	.800	.730	.669	.616	.566	.521	.478	.439	.404	.374
	50	.795	.750	.705	.662	.619	.580	.537	.503	.470	.440
30	30	.784	.731	.679	.632	.585	.543	.500	.484	.429	.400
	10	.773	.713	.657	.607	.559	.516	.471	.435	.401	.371
	50	.766	.726	.685	.645	.605	.567	.528	.494	.461	.433
10	30	.756	.709	.663	.619	.576	.535	.494	.459	.425	.398
	10	.747	.696	.644	.598	.552	.510	.468	.432	.398	.369
0	0	.732	.681	.631	.585	.539	.498	.456	.421	.387	.358

% Reflectancia Efectiva Techo (ρcc)	Pared (ρw)	Radio de Cavidad de Cuarto 1	2	3	4	5	6	7	8	9	10
	50	.844	.769	.701	.636	.579	.526	.478	.430	.392	.341
80	30	.819	.730	.655	.583	.521	.467	.417	.373	.334	.283
	10	.797	.697	.617	.542	.479	.427	.378	.332	.294	.244
	50	.826	.756	.690	.627	.569	.518	.470	.425	.368	.336
70	30	.803	.718	.646	.577	.516	.463	.413	.370	.331	.282
	10	.783	.690	.612	.537	.476	.423	.374	.330	.294	.244
	50	.791	.726	.668	.606	.553	.503	.457	.414	.378	.329
50	30	.772	.697	.631	.564	.507	.455	.406	.364	.327	.277
	10	.757	.671	.600	.530	.471	.419	.371	.328	.291	.242
	50	.759	.701	.647	.589	.536	.491	.444	.405	.369	.321
30	30	.746	.678	.616	.552	.497	.448	.401	.358	.322	.274
	10	.732	.656	.590	.523	.466	.415	.367	.325	.289	.240
	50	.732	.677	.626	.572	.524	.479	.436	.395	.361	.315
10	30	.720	.658	.601	.541	.489	.440	.395	.353	.318	.270
	10	.709	.641	.579	.515	.460	.410	.364	.323	.286	.238
0	0	694	.626	.565	.501	.446	.397	.350	.309	.274	.225

% Reflectancia Efectiva Techo (ρcc)	Pared (ρw)	Radio de Cavidad de Cuarto 1	2	3	4	5	6	7	8	9	10
	50	.828	.751	.680	.613	.554	.500	.448	.402	.365	.314
80	30	.803	.711	.632	.558	.496	.439	.388	.343	.305	.255
	10	.780	.677	.594	.516	.451	.398	.347	.301	.264	.215
	50	.811	.737	.670	.604	.544	.492	.442	.397	.360	.310
70	30	.787	.699	.624	.553	.490	.436	.384	.340	.302	.254
	10	.766	.670	.589	.512	.448	.394	.344	.299	.263	.215
	50	.776	.709	.648	.584	.529	.477	.430	.388	.350	.303
50	30	.757	.679	.609	.540	.481	.428	.377	.335	.298	.250
	10	.742	.652	.578	.505	.444	.390	.341	.297	.261	.214
	50	.746	.684	.627	.567	.514	.465	.417	.377	.342	.295
30	30	.732	.660	.595	.529	.471	.421	.372	.329	.293	.246
	10	.718	.638	.568	.498	.436	.387	.337	.295	.259	.211
	50	.719	.661	.608	.551	.500	.454	.409	.367	.333	.288
10	30	.707	.641	.581	.518	.464	.413	.367	.324	.289	.242
	10	.695	.623	.558	.491	.434	.382	.334	.293	.267	.209
0	0	.680	.608	.546	.478	.420	.369	.321	.279	.244	.197

Accesorios

Cat. No.
UNEH-26
Descripción:
Juego Standard para montaje de unidad Doble

Cat. No.
0500327
Descripción:
Juego de partes para reflectores 0500010-3, 6 y 11

Cat. No.
0500328
Descripción:
Juegos de partes para reflectores 0500010-1, 2 y 13

Cat. No.
0500329
Descripción:
Juego de partes para reflectores 0500010-4, 5, 7 y 8

BALASTRO REMOTO
Señale las especificaciones del Balastro

0500073

Tabla V Reflectancia efectiva de techo

% Reflectancia de Techo o Piso (1)	90				80				70			50			30				10		
2) % Reflectancia Pared	90	70	50	30	80	70	50	30	70	50	30	70	50	30	65	50	30	10	50	30	10
3) Radio de Cavidad de Techo o Piso																					
0	90	90	90	90	80	80	80	80	70	70	70	50	50	50	30	30	30	30	10	10	10
0.1	90	89	88	87	79	79	78	78	69	69	68	59	49	48	30	30	29	29	10	10	10
0.2	89	88	86	85	79	78	77	76	68	67	66	49	48	47	30	29	29	28	10	10	9
0.3	89	87	85	83	78	77	75	74	68	66	64	49	47	46	30	29	28	27	10	10	9
0.4	88	86	83	81	78	76	74	72	67	65	63	48	46	45	30	29	27	26	11	10	9
0.5	88	85	81	78	77	75	73	70	66	64	61	48	46	44	29	28	27	25	11	10	9
0.6	88	84	80	76	77	75	71	68	65	62	59	47	45	43	29	28	26	25	11	10	9
0.7	88	83	78	74	76	74	70	66	65	61	58	47	44	42	29	28	26	24	11	10	8
0.8	87	82	77	73	75	73	69	65	64	60	56	47	43	41	29	27	25	23	11	10	8
0.9	87	81	76	71	75	72	68	63	63	59	55	46	43	40	29	27	25	22	11	9	8
1.0	86	80	74	69	74	71	66	61	63	58	53	46	42	39	29	27	24	22	11	9	8
1.1	86	79	73	67	74	71	65	60	62	57	52	46	41	38	29	26	24	21	11	9	8
1.2	86	78	72	65	73	70	64	58	61	56	50	45	41	37	29	26	23	20	12	9	7
1.3	85	78	70	64	73	69	63	57	61	55	49	45	40	36	29	26	23	20	12	9	7
1.4	85	77	69	62	72	68	62	55	60	54	48	45	40	35	28	26	22	19	12	9	7
1.5	85	76	68	61	72	68	61	54	59	53	47	44	39	34	28	25	22	18	12	9	7
1.6	85	75	66	59	71	67	60	53	59	52	45	44	39	33	28	25	21	18	12	9	7
1.7	84	74	65	58	71	66	59	52	58	51	44	44	38	32	28	25	21	17	12	9	7
1.8	84	73	64	56	70	65	58	50	57	50	43	43	37	32	28	25	21	17	12	9	6
1.9	84	73	63	55	70	65	57	49	57	49	42	43	37	31	28	25	20	16	12	9	6
2.0	83	72	62	53	69	64	56	48	56	48	41	43	37	30	28	24	20	16	12	9	6
2.1	83	71	61	52	69	63	55	47	56	47	40	43	36	29	28	24	20	16	13	9	6
2.2	83	70	60	51	68	63	54	45	55	46	39	42	36	29	28	24	19	15	13	9	6
2.3	83	69	59	50	68	62	53	44	54	46	38	42	35	28	28	24	19	15	13	9	6
2.4	82	68	58	48	67	61	52	43	54	45	37	42	35	27	28	24	19	14	13	9	6
2.5	82	68	57	47	67	61	51	42	53	44	36	41	34	27	27	23	18	14	13	9	6
2.6	82	67	56	46	66	60	50	41	53	43	35	41	34	26	27	23	18	13	13	9	5
2.7	82	66	55	45	66	60	49	40	52	43	34	41	33	26	27	23	18	13	13	9	5
2.8	81	66	54	44	66	59	48	39	52	42	33	41	33	25	27	23	18	13	13	9	5
2.9	81	65	53	43	65	58	48	38	51	41	33	40	33	25	27	23	17	12	13	9	5
3.0	81	64	57	42	65	58	47	38	51	40	32	40	32	24	27	22	17	12	13	8	5
3.1	80	64	51	41	64	57	46	37	50	40	31	40	32	24	27	22	17	12	13	8	5
3.2	80	63	50	40	64	57	45	36	50	39	30	40	31	23	27	22	16	11	13	8	5
3.3	80	62	49	39	64	56	44	35	49	39	30	39	31	23	27	22	16	11	13	8	5
3.4	80	62	48	38	63	56	44	34	49	38	29	39	31	22	27	22	16	11	13	8	5
3.5	79	61	48	37	63	55	43	33	48	38	29	39	30	22	26	22	16	11	13	8	5
3.6	79	60	47	36	62	54	42	33	48	37	28	38	30	21	26	21	15	10	13	8	5
3.7	79	60	46	35	62	51	42	32	48	37	27	38	30	21	26	21	15	10	13	8	4
3.8	79	59	45	25	62	53	41	31	47	36	27	38	29	21	26	21	15	10	13	8	4
3.9	78	59	45	34	61	53	40	30	47	36	26	38	29	20	26	21	15	10	13	8	4
4.0	78	58	44	33	61	52	40	30	46	35	26	38	29	20	26	21	15	9	13	8	4
4.1	78	57	43	32	60	52	39	29	46	35	25	37	28	20	25	21	14	9	13	8	4
4.2	78	57	43	32	60	51	39	29	46	34	25	37	28	19	26	20	14	9	13	8	4
4.3	78	56	42	31	60	51	38	28	45	34	25	37	28	19	26	20	14	9	13	8	4
4.4	77	56	41	30	59	51	38	28	45	34	24	37	27	19	26	20	14	8	13	8	4
4.5	77	55	41	30	59	50	37	27	45	33	24	37	27	19	25	20	14	8	14	8	4
4.6	77	55	40	29	59	50	37	26	44	33	24	36	27	18	25	20	14	8	14	8	4
4.7	77	54	40	29	58	49	36	26	44	33	23	36	26	18	25	20	13	8	14	8	4
4.8	76	54	39	28	58	49	36	25	44	32	23	36	26	18	25	19	13	8	14	8	4
4.9	76	53	38	28	58	49	35	25	44	32	23	36	26	18	25	19	13	7	14	8	4
5.0	76	53	33	27	57	48	35	25	43	32	22	36	26	17	25	19	13	7	14	8	4

ALTURA DE MONTAJE :

DEPENDIENDO DE LA ALTURA DE - MONTAJE SE DEBERA CONSIDERAR. CUAL ZONA DE LA CURVA DEBERA TENER EL MAYOR PORCENTAJE DE FLUJO.

- DE 0° - 60° SE RECOMIENDA PARA - MONTAJES BAJOS (MENOS 4.5 MTS.)
- DE 0° - 45° PARA MONTAJES MEDIOS (DE 4.5 MTS. A 7.5 MTS.)
- DE 0° - 30° PARA MONTAJES ALTOS (MAS DE 7.5 MTS.)

ESPACIAMIENTO/ALTURA DE MONTAJE :

PARA OBTENER UNA BUENA UNIFORMIDAD EN EL PLANO DE TRABAJO. - SE DEBE RESPETAR LA RELACION - S/HM PROPIA DEL LUMINARIO.

a) CONOCER PUNTO DE LA CURVA - DONDE SE REDUCE EL FLUJO LUMINOSO A LA MITAD DEL TOTAL. (POR EJEMPLO 17°).

b) DIVIDIR EL PUNTO CONOCIDO - ENTRE 34 (17/34 = 0.5)

INTERPRETACION DE UNA CURVA ISOFOOTCANDLE

DEFINICION.- Es una línea plana de cualquier juego de coordenadas para mostrar todos los puntos de una superficie donde la iluminación es la misma.

USOS.- Se puede leer directamente los niveles en footcandles en puntos específicos abajo de un luminario montado a determinada altura.

Ejemplo: Referirse a la curva 820373. Cada círculo (de A hasta E), representan un punto abajo del luminario donde los niveles en footcandles son los mismos.

Para leer los niveles de footcandles, solamente se necesita conocer la MH del luminario. Por ejemplo, 1 10' de altura de montaje (MH), el círculo A representa 5 fc; sin embargo, a 20' de MH el círculo A representa 1.2 fc. Todos los valores son leídos en la tabla que aparece en la parte inferior de la curva.

El cuadriculado de la ilustración puede ser usado para determinar la distancia fuera del centro de los círculos que están directamente abajo del luminario. El lado de cada cuadro en la ilustración es siempre igual a la altura de montaje (MH) del luminario.

para un luminario montado a 10' el círculo A cae ligeramente afuera del punto colocado directamente abajo del luminario. El círculo D está a 30' de este punto.

VMVS2C100GPC
LAMP-100W Clear HPS
9500 LUMENS

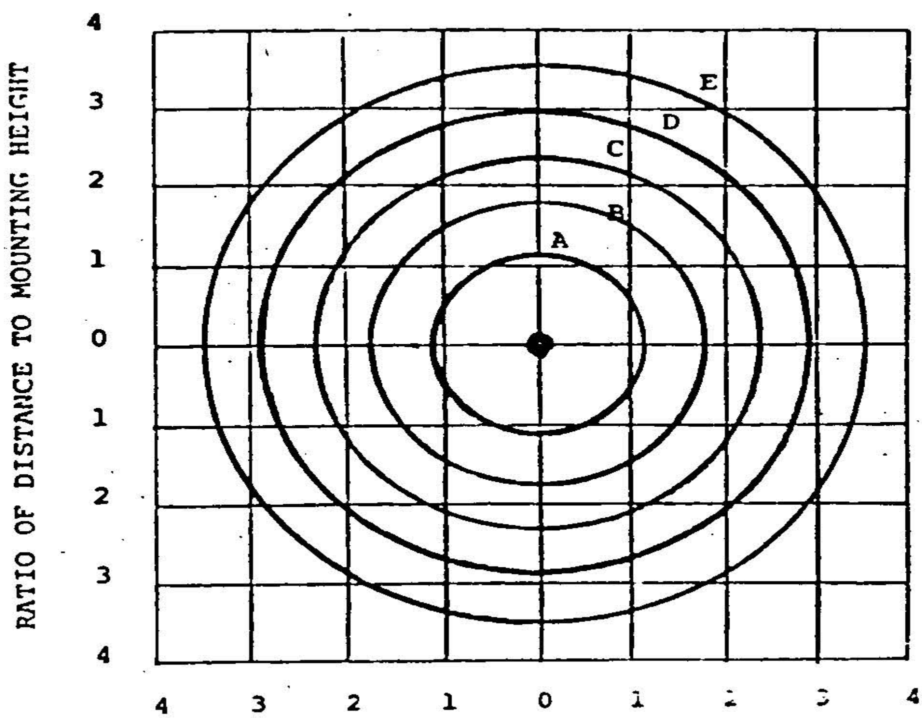
LIGHTING PRODUCTS
DIVISION
SYRACUSE, N. Y. 13201

CROUSE-HINDS

Figures shown are initial horizontal footcandle values at ground level.

Drawn By: VDM
Approved By:
Designed By:

Scale:
Date: 6/18/79
Drwg. No: 820373



RATIO OF DISTANCE TO MOUNTING HEIGHT

Footcandle Values for Isofootcandle Lines

	A	B	C	D	E	Mtg. Ht.
	5.0	2.0	1.0	0.5	0.20	10'
(2)	3.5	1.4	0.7	0.3	0.14	12'
	2.0	0.8	0.4	0.2	0.08	16'
(1)	1.2	0.5	0.2	0.1	0.05	20'

ENGR. 105-500

INFORMACION FOTOMETRICA DE LUMINARIOS FLUORESCENTES

Aunque los principios básicos son los mismos, la fotometría de los gabinetes fluorescentes es algo más complicado, ya que no son simétricos con relación al eje vertical. Lo que generalmente se hace en este caso, es establecer una curva de distribución para puntos situados sobre un plano vertical, a lo largo del eje del luminario y luego establecer otra curva sobre un plano vertical en ángulo recto con respecto al primero. Estas son las dos curvas que generalmente se publican para mostrar la distribución luminosa del luminario, se muestra en la figura. Sin embargo, para poder suministrar una información lo más completa para realizar los cálculos de iluminación, en los laboratorios de fotometría también determinan las curvas para planos que forman ángulos de 45° c los dos planos ya citados. Luego, por medio de fórmulas y tablas convenidas en la industria, se determina la cantidad de lumens que corresponde a cada zona.

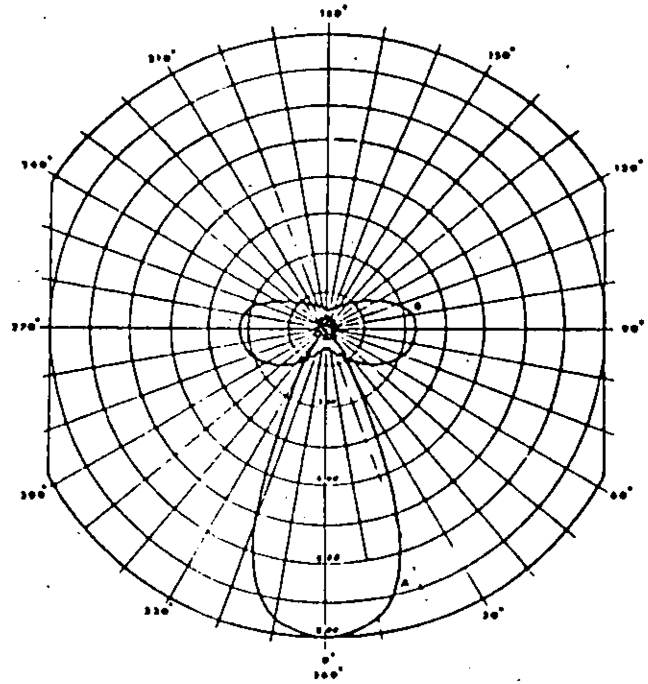


Fig. 2-30. Comparación de curvas de distribución luminosa. El artefacto B emite mayor cantidad de lúmenes que el artefacto A.

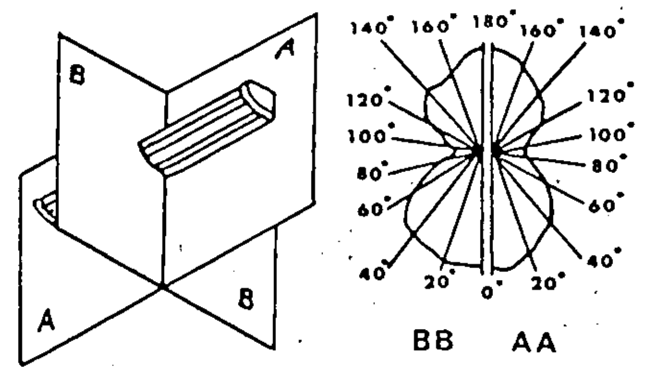


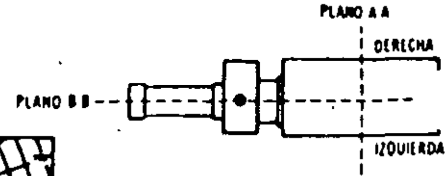
Fig. 2-32. Curvas de distribución luminosa de un artefacto fluorescente.

The Illuminator™

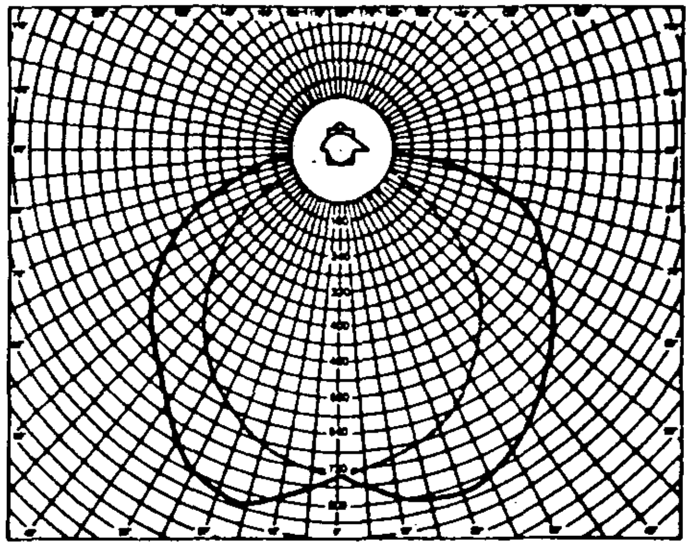
Datos fotométricos

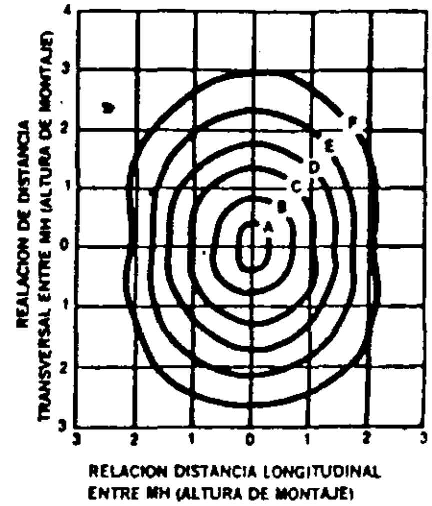
Illuminator de dos lámparas con Reflector (sin Guarda)

Lámparas: (2) 39 watt BIAX* fluorescente.



	CANDELAS EN PLANO A A		PLANO B B
GRADOS	IZQ	DER	LADO
0	729	729	729
10	782	797	703
20	820	821	658
30	757	777	562
40	648	709	488
50	567	632	370
60	474	535	239
70	340	469	109
80	201	312	21
90	102	116	
100	8	7	
110			
120			
130			
140			
150			
160			
170			
180			





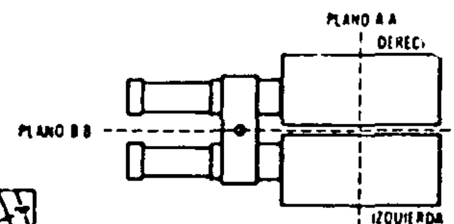
LEYENDA
—— PLANO A-A
A TRAVES DEL EJE DE LAMPARA
----- PLANO B-B
A LO LARGO DEL EJE DE LA LAMPARA

VALORES PARA LINEAS ISOFOOTCANDLE

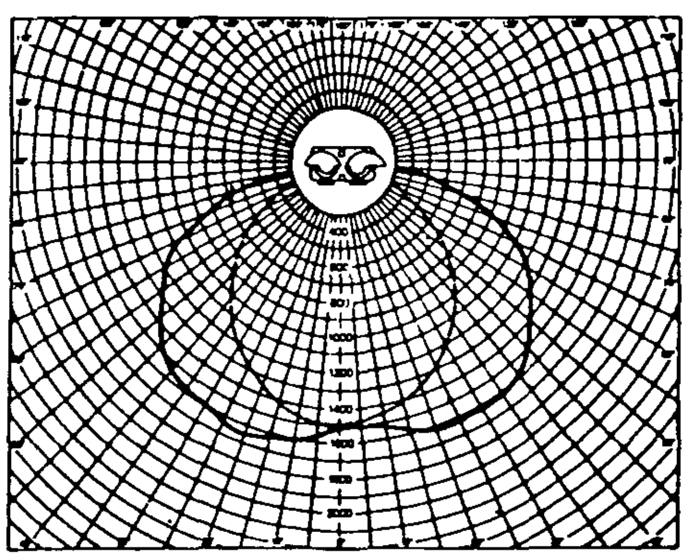
A	B	C	D	E	F	M H (en mts)
10 0	5.00	2.00	1.00	0.50	0.25	2.44
6.4	3.20	1.28	0.64	0.32	0.16	3.05
4.4	2.22	0.89	0.44	0.22	0.11	3.66
2.5	1.25	0.50	0.25	0.13	0.06	4.88

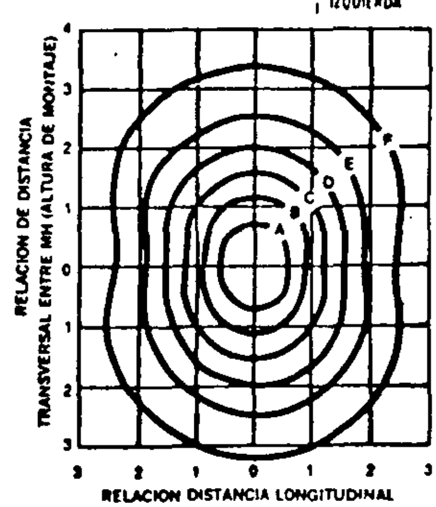
Illuminator de cuatro lámparas con Reflectores (Sin Guarda)

Lámparas: (4) 39 watt BIAX* fluorescente.



	CANDELAS EN PLANO A A		PLANO B B
GRADOS	IZQ	DER	LADO
0	1486	1486	1486
10	1601	1520	1448
20	1633	1615	1346
30	1570	1602	1199
40	1530	1558	1000
50	1343	1390	763
60	1162	1208	492
70	803	921	225
80	375	488	45
90	138	168	2
100	13	18	1
110	2	6	
120	1	4	
130			
140	2		1
150		1	1
160			1
170	2	1	1
180	2	2	2



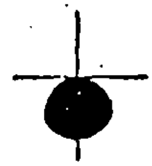
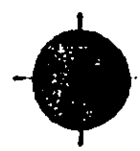


LEYENDA
—— PLANO A-A
A TRAVES DEL EJE DE LAMPARA
----- PLANO B-B
A LO LARGO DEL EJE DE LA LAMPARA

VALORES PARA LINEAS ISOFOOTCANDLE

A	B	C	D	E	F	M H (en mts)
8.0	4.00	2.00	1.00	0.50	0.20	3.05
5.6	2.78	1.39	0.69	0.35	0.14	3.66
3.1	1.56	0.78	0.39	0.20	0.08	4.88
2.0	1.00	0.50	0.25	0.13	0.05	6.09

*BIAX es un marca comercial de la Compañía General Electric.

CLASIFICACION	% DE LUZ RESPECTO A LA HORIZONTAL ARRIBA	ABAJO	DISTRIBUCION DE POTENCIA LUMINICA
DIRECTA	0-10%	90-100%	
SEMI-DIRECTA	10-40%	60-90%	
DIRECTA INDIRECTA*	40-60%	60-40%	
GENERAL DIFUSA	60-40%	40-60%	
SEMI-INDIRECTA	60-90%	10-30%	
INDIRECTA	90-100%	0-10%	

* SOLO CLASIFICACION IES

Figura 1. CLASIFICACIONES CIE-IES.

FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

T E M A 6

L U M I N A R I O S.

NOTAS PREPARADAS POR EL ING. ALEX RAMIREZ RIVE[illegible]

Palacio de Minería Calle de Tacuba 5 Primer piso Deleg. Cuauhtémoc 06000 México, D.F. APDO. Postal M-2285
Teléfonos: 512-8955 512-5121 521-7335 521-1987 Fax 510-0573 521-4020 AL 26

TEMA

LUMINARIOS

La palabra "Luminario" es el término correcto para describir lo que comunmente se conoce como "accesorio de iluminación" (lighting fixture). La palabra "accesorio" (fixture) implica equipo permanentemente instalado. Más de 100,000 diferentes tipos y estilos de luminarios se hacen hoy en día. Los más importantes y usados se describen en este capítulo.

VII.1.- COMPONENTES DE LOS LUMINARIOS

Un luminario es una unidad de iluminación completa consistiendo de una o más lámparas con algunos o con todos los componentes siguientes:

a) Porta lámparas y sockets para posocionar y conectar las lámparas a la fuente.
b) Balastros para encender y operar las lámparas.
c) Reflectores para dirigir la luz en la dirección deseada.
d) Componentes difusores y de escudo tales como lentes, difusores, y louvers para distribuir la luz y evitar el reflejo.
e) Housings para proteger los componentes mencionados junto con las conexiones y otros equipos eléctricos.

Los componentes del luminario trabajan juntos para determinar el funcionamiento del luminario.

Se usan dos medidas para estimar el funcionamiento del luminario:

a) Eficiencia del luminario.- Mide el porcentaje de lumens de lámpara que dejan el luminario, comparado con la razón de lumens totales de lámpara. Asì un luminario abierto tendrá generalmente una mayor eficiencia que el mismo luminario equipado con lente (difusor) ya que este absorverá la luz.

b) Coeficiente de utilizaciòn del luminario.- Usado en calculos de iluminación para describir el porcentaje de lumens de lámpara que llegan a la superficie de trabajo. Esta característica depende de las dimensiones del cuarto, así como del tipo del luminario y de los valores de las tablas impresas en los catálogos de fabricantes de luminarios.

VI.2.- TIPOS DE LUMINARIOS

Los luminarios pueden ser clasificados en grupos dependiendo de una o más características, incluyendo la distribución de luz, altura de montaje, su función específica, reflector o tipos de lentes, y el nombre del diseño.

VI.2.a.- CLASIFICACION POR DISTRIBUCION DE LUZ

Una de las más importantes características de un luminario es su patrón de distribución. Los patrones más comúnes de distribución, como se muestra en la figura 1, son:

a) Luz directa.- Con el luminario montado encima del área a iluminar y con su salida directa descendente.

b) Luz indirecta.- El luminario dirije toda su luz hacia el techo o pared, transmitiendola al àrea iluminada para reflejar la luz hacia el área de trabajo.

c) Directa.- En el cual la luz es principalmente dirigida al lugar de trabajo pero tambièn tiene una distribuciòn indirecta.

d) Semi directa.- En el cual la distribución indirecta es el porcentaje más grande de la salida.

e) Directa/Indirecta.- En el cual las dos distribuciones son aproximadamente iguales.

f) General difuso.- El luminario radía luz en igual cantidad en todas direcciones.

g) Direccional.- En el cual la luz es dirigida a una dirección específica.

h) Asimétrico.- En el cual la luz es dirigida con más intensidad hacia un lado que hacia el otro.

VI.2.b.- CLASIFICACION POR TIPO DE MONTAJE

La manera en que un luminario está montado o conectado es una característica común de clasificación. Los montajes más comúnes se muestran en la figura 2 y se enlistan a continuación:

a) Luminarios empotrados.- Se meten dentro de la pared o techo. Un luminario semiempotrado se mete solo parcialmente en la superficie dejando el resto visible.

b) Luminarios para sobre poner (surface-mounted).- Se describen usualmente como "montes de pared" o "montes de techo". Estos luminarios son totalmente visibles.

c) Luminarios pendientes.- Están suspendidos del techo por un cable, tubo o cadena que también lleva el cable eléctrico a la lámpara. A estos algunas veces se les llama luminarios suspendidos especialmente cuando se necesita suspender más de un miembro.

d) Bracket de pared (Wall-Bracket).- Están montados en la pared con un seguro que generalmente es parte del diseño de todo el luminario.

e) Luminarios Post-top.- Están diseñados para montarse encima de un poste para exteriores.

f) Luminario tipo "under cabinet" ilumina "countertops".

g) Luminarios tipo track.- Están montados en un riel electrificado.

h) Luminarios tipo mueble integrado.- Están montados permanentemente para divisiones de oficinas o para ser parte de sistemas de estaciones de trabajo.

i) Luminario portátil.- Puede ser trasladado fácilmente y conectado a una salida eléctrica estandar.

VI.2.c.- CLASIFICACION POR FUNCION O NOMBRE TRADICIONAL

Muchos luminarios tienen nombres relacionados con su función, tales como downlights, wall washer, luces de paso, lámparas de mesa y luz de pizarrón. Se debe recordar que los usos reales de un luminario no se limitan a los sugeridos por sus nombres.

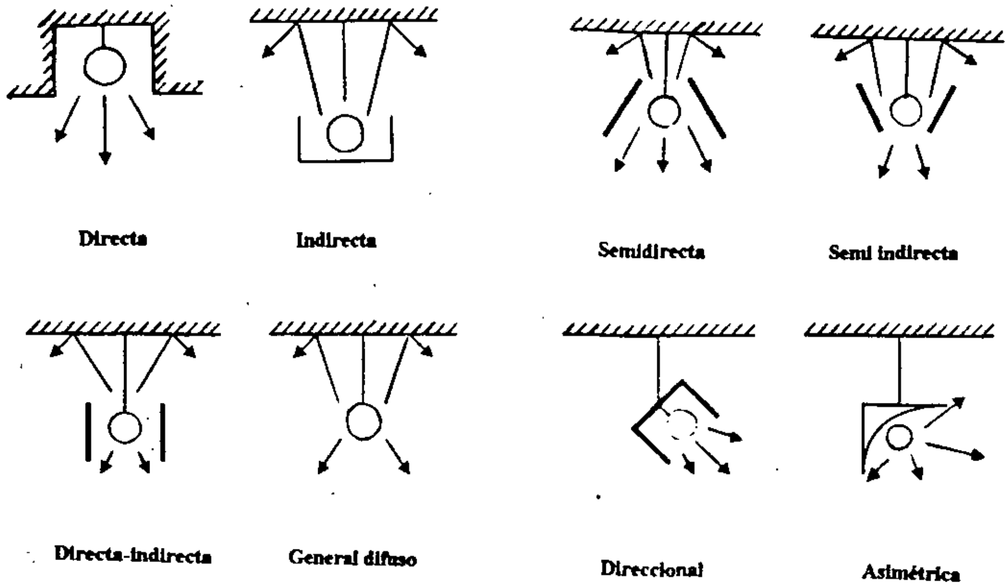


Figura 1.Tipos de distribución de luz

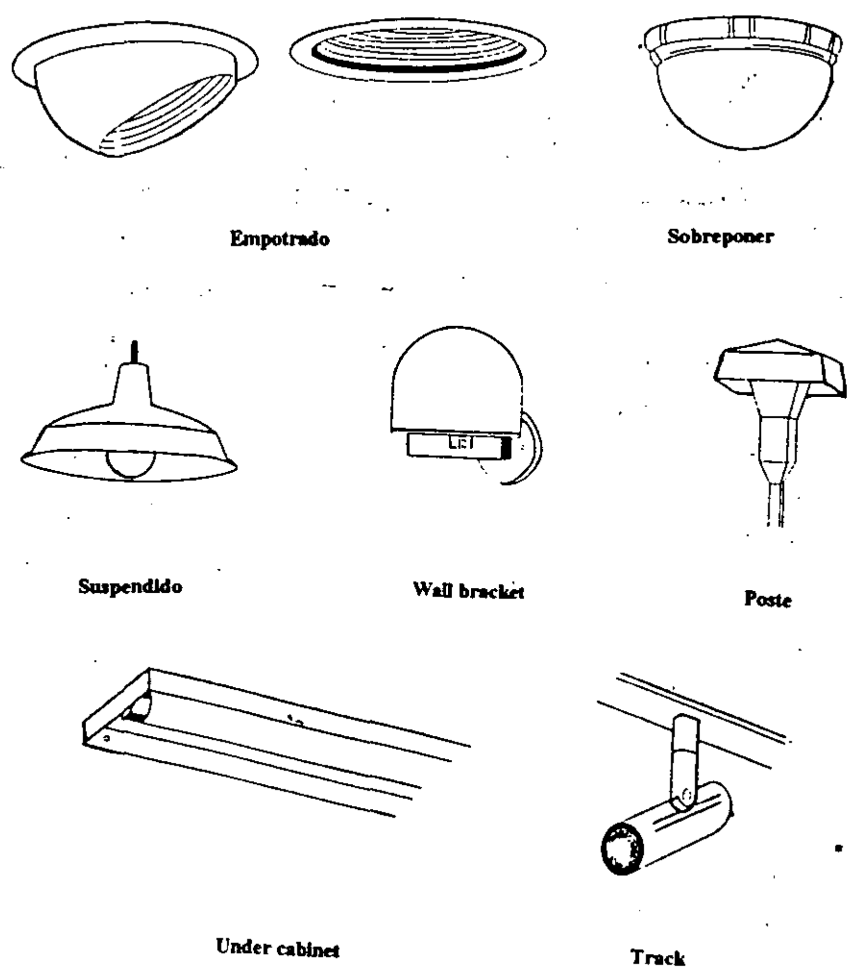


Figura 2.Tipos de montajes

Otros luminarios tienen un diseño tradicional o historico, y algunos luminarios modernos se usan de forma familiar o tradicional, por ejemplo, los candelabros, los candeleros o los faroles.

VI.2.d.- CLASIFICACION POR SU FORMA

Es común referirse a un luminario por su forma, especialmente si son llamativos, estos se muestran en la figura 3 y se enlistan a continuación:

a) El "Shoebox" es moderno para luminarios de carreteras.

b) El Cabeza de cobra (cobra head) es un luminario refractor convencional para iluminación de calles.

c) El "Lollipop shape" son luminarios en forma de globo colocados en al final del poste.

d) El "Wall slot" da la apariencia de un luminario continuo corriendo paralelamente a la pared.

e) El "metal troffer" es el luminario fluorescentes para empotrar más usado.

f) El "top hat" es un downlight empotrable.

VI.2.f.-CLASIFICACION POR EL TIPO DE COMPONENTES

En muchos casos, el nombre del luminario incluye una descripción de un componente específico que hace al luminario notable.

Ejemplos comunes se describen a continuación y se muestran en la figura 4.

a) Troffer parabólicos.- Usados para fluorescentes equipados con louvers diseñados para eliminar luz extraña y esconder a las lámparas de la luz directa.

b) Troffer prismático.- Llamado así por sus lentes difusores sobre la cara del troffer.

c) Fresnel.- Llamado así por su tipo de difusor usado para luz suave, y para lamparas teatrales de haz variable.

d) Elipsoidales.- Llamados así debido a los reflectores elipsoidales encontrados en downlights empotrables pequeños.

e) Wraparound.- Usados para luminarios fluorescentes envuesto de difusores prismáticos.

VI.3.- TIPOS Y ESTILOS DE SISTEMAS DE ILUMINACION GENERAL

Existen miles de diferentes tipos de luminarios en los sistemas de iluminación actuales, pero pueden ser divididos dentro de categorias generales, incluyendo la iluminación arquitectónica, oficinas generales e iluminación comercial, iluminación industrial, iluminación decorativa, iluminación interior especial e iluminación exterior para edificios para excaleras de escape y seguridad.

VI.3.a.- ILUMINACION ARQUITECTONICA

La iluminación arquitectónica se refiere a la iluminación de equipo oculto de la vista o integrado al diseño del edificio, creando efectos de iluminación sin una fuente aparente. El equipo de iluminación arquitectónica es ampliamente usado en todo tipo de edificios y es común encontrarlos en edificios contemporaneos.

1. DOWNLIGHT.

Los Downlights también llamados "botes", son usados en muchos lugares residenciales y comerciales. Los Downlights son generalmente empotrados, luminarios directos usualmente utilizados para iluminar lugares contemporaneos de alta calidad, tales como lobbies de hoteles y salas residenciales. Pueden ser equipados con incandescentes, con tungsteno halógeno, HID, o con lámparas fluorescentes de baja potencia. Se mencionan a continuación los diferentes tipos de Downlights que también se muestran en la figura 5.

a) Deflectores para usarse con reflector o con lámparas PAR.

b) Conos parabólicos para usarse con incandescentes y algunas lámparas fluorescentes compactas.

c) Conos elipsoidales para usarse con incandescentes, HID, o con lámparas de tungsteno halógeno.

A los Downlights de bajo voltaje se les llama algunas veces pin spots, para iluminación de acento para pequeñas aberturas.

Los Downlights son seleccionados en base al tamaño de apertura, al espacio disponible encima del techo, al esparcimiento deseado del haz y a su costo. El ángulo de Cut-off, el ángulo en el cual la fuente de luz es visible; son criterios importantes para los Downlights, mientras más alta sea la altura de montaje el ángulo de Cut- off será más pequeño para prevenir problemas de reflejo.

2. WALL WASHERS Y WALL SLOTS

Los "wall washers" y los "wall slots" son luminarios designados para la iluminación amplia de las paredes de un cuarto.

Los "wall washers" están diseñados para iluminar las paredes uniformemente del techo al piso; los "wall slots" están diseñados para estar al raz del techo, creando un efecto de textura en la superficie de paredes irregulares, tales como piedra o ladrillo.

Al estar al raz se puede lograr que el techo tenga la apariencia de flotar encima de las paredes.

Algunos ejemplos importantes se mencionan a continuación:

a)El "wall washer" eyelid empotrable da muy buena iluminación a la pared mientras proteje al cuarto de la vista de la fuente de luz.

b) El Downlight-Wall Washer está diseñado para dispersar luz hacia una pared mientras aparece un Downlight en el otro lado del cuarto.

c)Wall washer semi empotrado incluyendo luminarios tipo track, generalmente tiene un difusor que uniformiza la luz en la pared.

Los "wall slots" con louver utilizan un louver o un deflector para ocultar la fuente de luz dentro del canal.

La selección entre el "wall washer" y el "wall slots" dependen de el efecto deseado. Para paredes con pinturas, donde la luz debe ser dispersada uniformemente, el "wall washer" es el más común. Los "wall slots" son mejores para dar la textura de una superficie vertical.

3. ILUMINACION DE ACENTO

La iluminación de acento es similar en operación a los Downlights, pero están diseñados para resaltar objetos tales como pinturas, mercancias o detalles especiales de diseños arquitectónicos. Las principales luces de acento se muestran en la figura 6.

a) Luminario de acento empotrable y ajustable típicamente usa fuentes de luz tipo PAR, R, o de bajo voltaje; el ajuste de la luz se hace dentro del luminario.

b) El proyector framing empotrable utiliza difusores, shutters, y/o proyectores patrones para efectos especiales.

c) Luminario semiempotrado "eyeball"tiene una bola ajustable que es visible debajo del techo, y es fácil de ajustar.

Luminarios "pull down" emplean housings ajustables para que puedan ser colocados y orientados.

4. ILUMINACION DE TECHO Y PAPED

La iluminación de techo se usa para iluminar techos desde una fuente escondida. Esta requiere de una fuente de luz lineal como fluorescentes o de lámparas incandescentes de bajo voltaje.

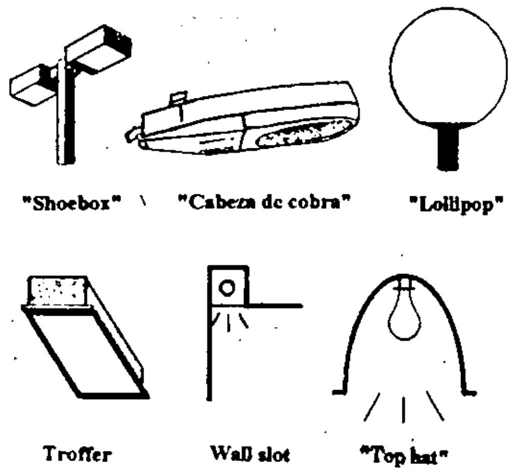


Figura 3.Formas reconocibles de luminarios

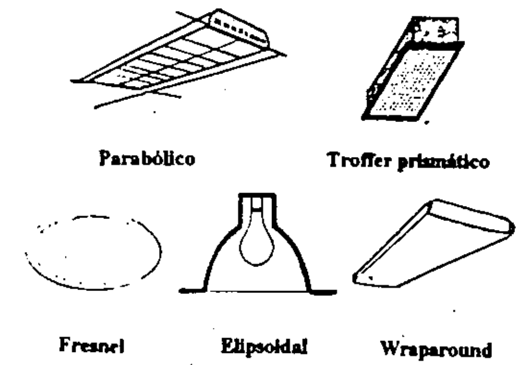


Figura 4.Luminarios nombrados según sus componentes

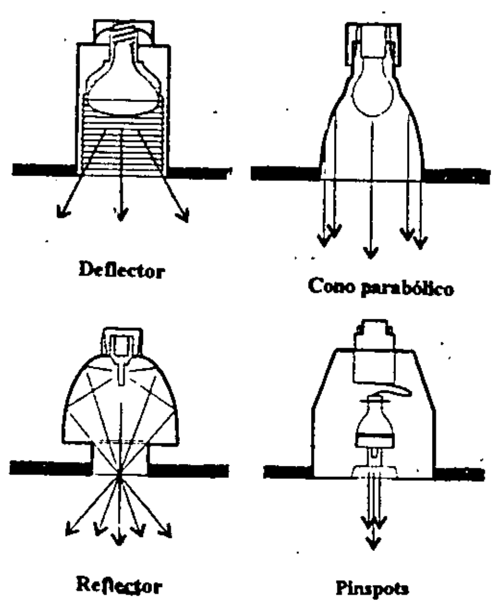


Figura 5.

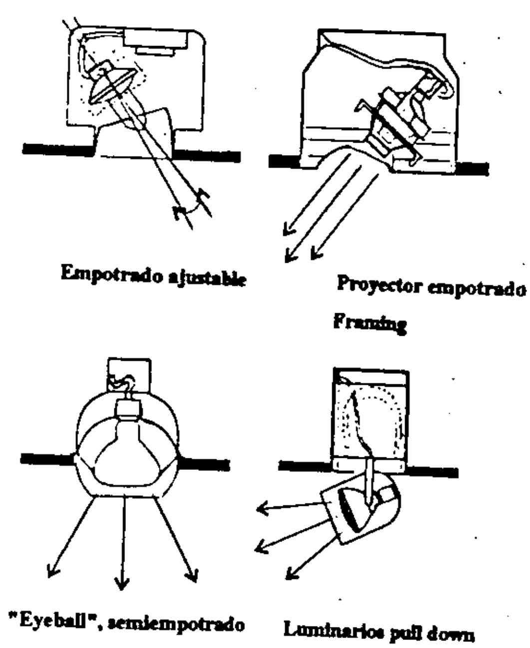


Figura 6.Luces de acento

La iluminación de pared consiste en fuentes escondidas de luz para iluminar paredes, detallar estantes etc.

La iluminación de pared también emplea fuentes lineales.

La figura 7 muestra este tipo de iluminación.

5. LUCES DE PASO

Las luces de paso son luminarios compactos diseñados para empotrarse en paredes para la iluminación de escaleras. Un nuevo luminario utiliza incandescente de bajo voltaje para ser empotrado a los lados de los pasamanos. Existen luminarios para usarlos con incandescentes estandar, para bajo voltaje y con compacto fluorescente.

VI.3.b.-ILUMINACION COMERCIAL Y PARA OFICINAS

Los sistemas de iluminación comercial y de oficinas generales son diseñados para iluminar areas amplias con niveles relativamente uniformes. La mayoría de las instalaciones son integradas dentro de techos suspendidos, con cada luminario tomando el lugar de un panel en la rejilla del techo.

1. TROFFERS.

Los Troffers son luminarios tipo caja que generalmente se ponen en plafones falsos de tal forma que el luminario quede encima del techo y la cara del luminario quede nivelado con el techo.

b)Las lámparas.- Comunmente fluorescentes, se colocan dentro del housing y la luz sale al espacio por la cara del lumianrio.

Los troffers están diseñados para ajustarse a los sistemas de plafones falsos existentes; los tamaños comunes son 1 por 4 pies, de 2 por 4 pies, y de 2 por 2 pies, además de que se tienen otros tamaños. El housing del troffer es un poco más pequeño que la rejilla, y esta soportada por una pestaña en el perímetro que descansa en los rieles del plafón falso.

A los troffers se les nombra dependiendo del método empleado para obtener su distribución de luz como se muestra en la figura 8.

El llamado difusor prismático usa un lente prismático plano formado por pequeños prismas triangulares en la superficie exterior para asegurar una amplia distribución.

El llamado difusor plano usa un lente de plástico translúcido para expandir la luz y esconder a las lámparas de la vista.

El louver parabólico es un troffer abierto con louvers en forma de parábola para enfocar la distribución de luz hacia abajo y para esconder las lámparas de la vista.

El louver "egg crate" es otro troffer abierto que lleva un set fino de louvers para esconder a la fuente de luz de la vista y para limitar la distribución de luz a una zona estrecha.

El troffer para fluorescente es por mucho el más usado en oficinas, escuelas e iluminación de lugares comerciales. Como el trabajo realizado en estos lugares cambian continuamente, el diseño del troffer es de gran interes para los fabricantes de luminarios.

En años anteriores los troffers tuvieron varias improvisaciones en sus componentes incluyendo los sistemas de reflectores y louvers más eficientes. Una especial area en el desarrollo de los troffers ha sido el diseño de sistemas de iluminación para usarse en lugares con intensivo trabajo de computadora y con terminales de video.

VI.3.c.- LUMINARIOS COMERCIALES

Los luminarios comerciales son un amplio rango de luminarios fluorescentes diseñados para iluminación comercial en general. Estos luminarios son especialmente colocados al raz del techo o suspendidos por cadenas, y son fuentes efectivas de bajo costo para iluminación de lugares de trabajo, existen diferentes tipos:

a) Luminarios surface-mounted, son troffers con cuatro lados terminados. Son disponibles con difusores o con louvers.

b) Los luminarios Wrap arounds tienen difusores que rodean completamente las lámparas fluorescentes.

c) Los luminarios strip lights tienen un chasis expuesto y lámparas visibles.

d) Los luminarios fluorescentes con louvers tienen extremos pintados y abertura con louvers.

1. SISTEMAS DE ILUMINACION SUSPENDIDA

Aunque los luminarios comerciales puedan ser usados como luminarios suspendidos, existe una clase especial de alta calidad y bien terminados luminarios diseñados para usarse en oficinas y escuelas. La mayoría de estos productos tienen distribución indirecta y algunos están diseñados especificamente para trabajos con terminales de video (ver fihura 9).

VI.3.d.- ILUMINACION INDUSTRIAL Y DE TRABAJO

La iluminación industrial y de tiendas emplea luminarios diseñados para tener durabilidad, eficiencia y bajo costo. Muchos de estos luminarios son disponibles en versiones para corrosión o ambientes explosivos: Existen varios tipos de luminarios industriales.

Los fluorescentes industriales exponen a las lámparas con un reflector poco profundo.Los accesorios incluyen protectores de lámpara y cables y housings resistentes a la corrosión.

Los luminarios tradicionales de pie para incandescentes, compacto fluorescentes y lámparas HID son llamados frecuentemente "RLMs" o "Luces de Fábrica" (Ver figura 10).

Los luminarios montables tipo globo se usan para HIDs, compactas fluorescentes y lámparas incandescentes. Se les llama "Jelly Jars".

Los luminarios industriales para HID con reflectores de alta eficiencia están diseñados para alturas de montaje específicas, como unidades para distribución amplia en alturas de bahía baja o unidades para distribución angosta en alturas de bahía alta.

Luminarios para propósitos especiales son diseñados para aplicaciones específicas como iluminación de almacenes o iluminación para inspecciones de fabricación.

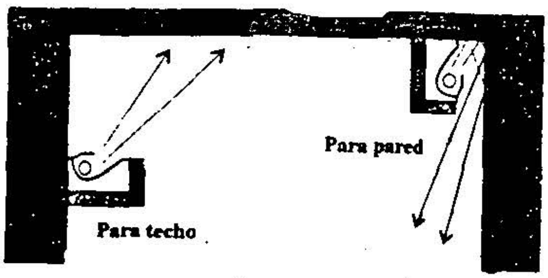


Figura 7.Iluminación de techo y pared

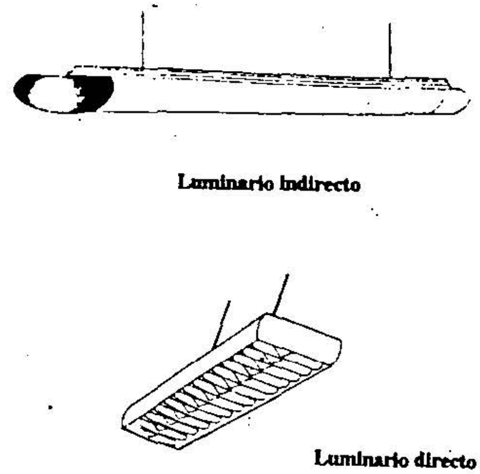


Figura 9.Luminarios suspendidos

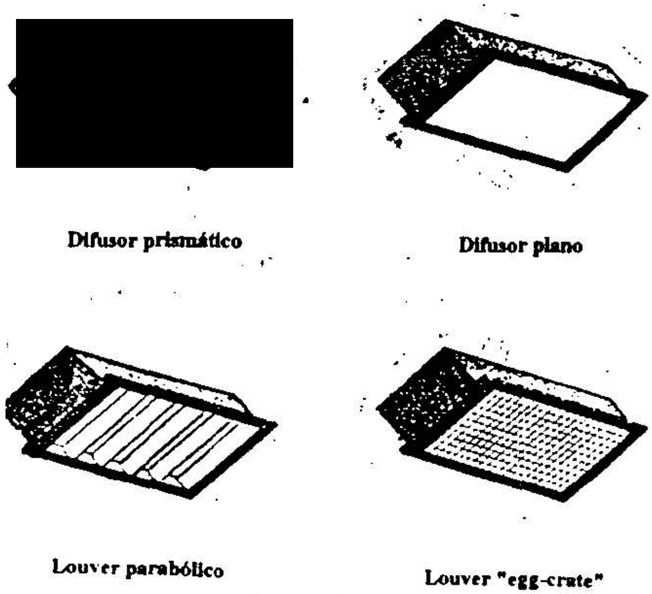


Figura 8.Troffers

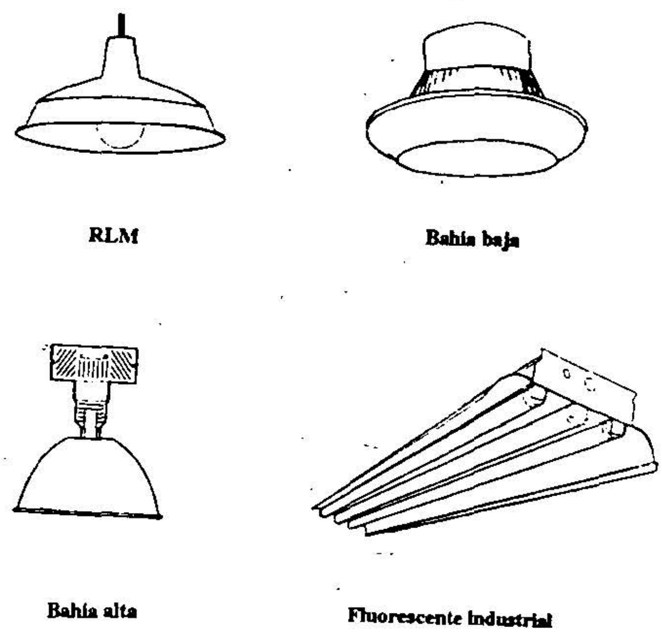


Figura 10.Luminarios industriales

1. ILUMINACION PARA EXHIBICIONES

El equipo para iluminación de exhibiciones se diseña para la iluminación de mercancías.

Aunque cualquier tipo de iluminación puede ser usado para estos propósitos, existen muchos sistemas de iluminación diseñados especificamente para estas funciones.

2. SISTEMAS DE ILUMINACION TRACK Y CABLEADO

La iluminación track consiste de una tira de aluminio resaltado con aislación plástica interna y conductores eléctricos. Los luminarios llamados track lights se soportan y toman su energía de la tira de aluminio. Estos luminarios pueden ser posicionados en cualquier lugar a lo largo del track, ofreciendo un sistema muy flexible.

La mayoría de los tracks opera a 120 Volts, y pueden tener de uno a cuatro circuitos separados para regular la potencia.

La iluminación open-wire utiliza cables desnudos o tubos energizados a bajo voltaje para encender la iluminación. Como la iluminación track es fácil de instalar y muy flexible.

3. ILUMINACION SEMI-TEATRAL

Para la iluminación de efectos especiales siempre se desea utilizar verdaderos instrumentos teatrales o semi-teatrales. Los equipos más utilizados se describen abajo; y uno de ellos se muestra en la figura 11.

Los spots de bajo voltaje son equipados generalmente con lámparas PAR de 6 ó 12 Volts.

Los Elipsoidales utilizan lentes, obturadores y/o filtros de color para producir diferentes efectos especiales.

El fresnel emplea lentes y variables haces de luz para producir un intensa distribución apropiada especialmente para artículos de arte.

4. ILUMINACION DE VITRINAS

Existe un problema especial para la iluminación en vitrinas, y es que necesita fuentes de luz lineales y pequeñas; esto ha llevado a que se necesite equipo especial de iluminación.

Debido a la proximidad de las lámparas y los objetos, el infrarojo y radiación ultravioleta del sistema de iluminación pueden ser factores determinantes. La mayoría de los sistemas de ilumianción de vitrinas son diseñados para minimizar el calor.

Las lámparas "T" incandescentes de bajo voltaje son las más antiguas y baratas de la iluminación para vitrinas, sin embargo son las más calientes y las menos eficientes.
Sistemas de iluminación de bajo voltaje de Incandescentes y halógenas tienen un diámetro menor y producen menos calor que las lámparas T.

Sistemas de fibra óptica de fuente remota son los más caros de la iluminación para vitrinas. Los sistemas de tubos fluorescentes son un poco mas lárgas en diámetro, sin embargo son menos caros y producen muy poco calor.

VI.3.e.- ILUMINACION DECORATIVA Y ORNAMENTAL

La iluminación ha evolucionado de la vela, gasolina y gas; muchos de los ornamentos tradicionales han entrado a la era de la iluminación eléctrica con muy pocos cambios en sus diseños y además siguen siendo populares en sus formas clásicas.

Los candelabros son luminarios suspendidos formales y muy elaborados. Originalmente diseñados para velas, fueron acoplados a las lámparas eléctricas no hace mucho en la historia de la iluminación eléctrica.

Los candeleros de pared son luminarios que se montan en la pared y que originalmente sostenian velas. Se usa más frecuentemente para iluminación difusa de la pared adyacente o del techo.

Los faroles son luminarios decorativos usados tradicionalmente para exteriores y para iluminación de pasillos.

El aumento de la modernización en la arquitectura trajo consigo el uso de nuevas tecnologías y nuevos materiales. Dos luminarios de pie comunes vienen de esta tradición:

Los luminarios de metal o de vidrio decorativo colgantes son modernas interpretaciones de candelabros.

Los brackets de pared son modernas interpretaciones de los candeleros de pared. Algunos de estos luminarios se muestran en la figura 12.

1. ILUMINACION PORTATIL

La iluminación portátil se define como el equipo de iluminación que puede ser colocado y conectado en cualquier lugar deseado. La mayoría de la iluminación residencial es portátil, así como en algunos lugares de trabajo. ALgunos de los luminarios portátiles más comunes se describen a continuación.

a) Las lámparas de mesa y piso son estilos tradicionales utilizados en casas y en lugares semejantes,tales como los cuartos de un hotel, para tareas locales e iluminación en general.

b) Los Torchieres son lámparas de piso de alta potencia diseñadas para iluminación de techos. Estas proveen iluminación general reflejada.

c) Las lámparas de escritorio tienen muchos diseños importantes, tales como las lámparas clásicas para arquitectos o las lámparas fluorescentes ajustables usadas por dibujantes e ingenieros.

d) La iluminación de acento portátil se usa para resaltar objetos individuales, tales como plantas o cuadros.

VI.3.f.- SISTEMAS DE ILUMINACION ESPECIALES PARA INTERIORES

Existen numerosos tipos de iluminación interior muy creativos y decorativos, la mayoría creados en los últimos 20 años de un acelerado interés en el diseño y tecnología de la iluminación.

Muchos de estos luminarios tienen una fácil clasificación por ser productos unicos.

a) Sistemas modulares de bajo voltaje emplean muchas lámparas pequeñas (menos de 5 watts cada una) para crear un efecto centellante usado en pasillos teatrales.

b) Sistemas mobiliarios integrados.- Incorporan luminarios construidos en oficinas de trabajo para la iluminación de tareas o de ambientación.

c) Sistemas de función integrados.- Incorporan iluminación a un solo housing con una o más aplicaciones eléctricas, tales como bocinas, ventiladores o detectores de humo.

Sistemas de fibra óptica de una unidad de iluminación, se usa en exteriores con la fuente en un lugar remoto con las fibras llevando la luz al destino deseado.

VI.3.g.- ILUMINACION DE EXTERIORES

Uno de los avances de la iluminación eléctrica fué el de remplazar las lámparas de gas como fuente de la iluminación de calles, banquetas, parques y otros. El equipo de iluminación de gas dió las bases para el diseño de muchos luminarios; como los mostrados en la figura 13.

1. LUMINARIOS DE POSTE

Los luminarios de poste son usados para iluminar espacios exteriores grandes tales como estacionamientos o carreteras. La mayoría de los postes de alumbrado de calles tienen entre 12 y 40 pies de alto (3.6 y 12 metros). Los postes con más de 40 pies de alto (12 metros) se conocen como luminarios de poste alto, mientras que los luminarios montados a menos de 40 pies (12 metros) se les llama luminarios peatonales altos. Los luminarios para montarse en los postes incluyen:

a) Luminarios decorativos como globos, cubos, bellotas y faroles.

b) Los luminarios de poste alto llevan luminarios "cobra head" o "shoe boxes".

c) Faros de inundación y luces de seguridad.

d) Luminarios con funciones especiales, tales como para estacionamientos o para pistas de aeropuertos.

2. WALLPACKS

Los "wallpacks" son relativamente de bajo costo, de distribución ancha y diseñados para montarse en la superficie de una pared exterior. Emplean generalmente lámparas de HID o fluorescentes y in balastro integrado en un housing resistente al vandalismo. Estos luminarios proveen iluminación segura a bajo costo.

3. FAROS DE INUNDACION (FLOODLIGHTS)

Son luminarios que pueden ser montados en el piso, arriba de edificios o de postes. Pueden ser usados para iluminar patios, edificios y areas de seguridad, o cualquier area exterior amplia.

4. ILUMINACION ARQUITECTONICA EXTERIOR

El crecimiento de la importancia de la iluminación de arquitecturas exteriores ha llevado ha desarrollar importantes y diferentes tipos de luminarios:

a) Los "Bollards" son luminarios pequeños para iluminar carreteras y caminos con baja altura.

b) Los luminarios y postes ornamentales juegan un papel significativo en la apariencia diurna y nocturna en plazas y parques.

c) Los faroles y braquets se usan generalmente cerca de las entradas a edificios, teniendo un estilo complementario a la arquitectura del edificio; de hecho, muchos arquitectos diseñan los faroles especificamente para reflejar los elementos principales del edificio.

Las luces de fachada son luminarios especificamente diseñados para iluminar fachadas y siluetas de edificios durante la noche.

Estos luminarios se muestran en la figura 14.

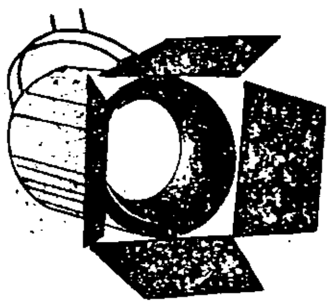
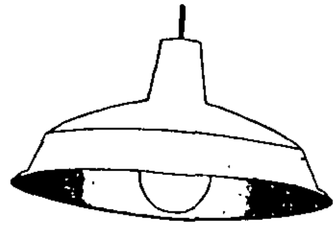
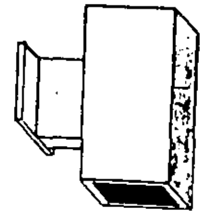


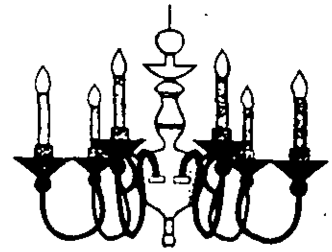
Figura 11.Luminario semi-teatral



Iluminación para fábricas



Wall bracket



Candelabro

Figura 12.Luminarios tradicionales

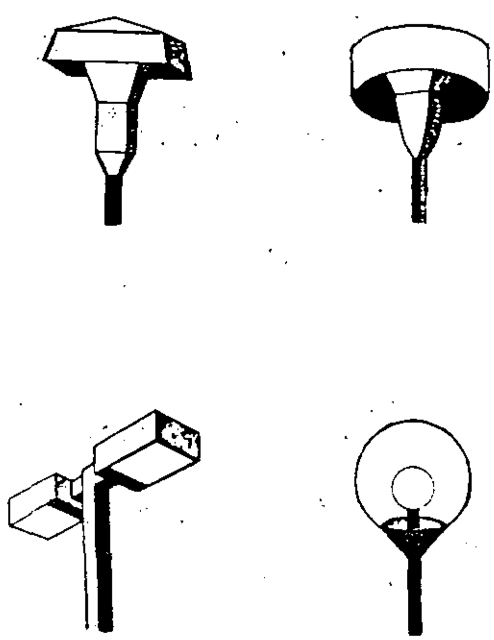
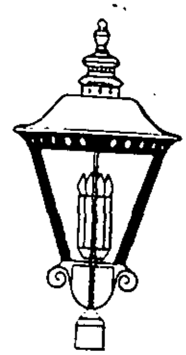
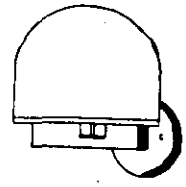


Figura 13.Luminarios para exteriores tipo poste

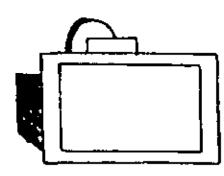


Farol

Bollard



Wall bracket



Fachada

Figura 14.Iluminación arquitectónica para exterior

5. ILUMINACION DE PAISAJES

La iluminación para acentuar el paisaje y no solamente la arquitectura se ha convertido en una importante aplicación del diseño de iluminación. Se ha diseñado equipo especial para condiciones ásperas y humedas para iluminación de paisajes, incluyendo toda una familia completa de diferentes diseños.

6. ILUMINACION DESDE TIERRA

Esta se utiliza generalmente para iluminar hacia arriba plantas y edificios aledaños. Se utilizan muchos tipos:

a) Iluminación desde tierra incluyendo los luminarios tipo sellados y los "direct burial".

b) Los luminarios "box mounted" incluyen "bullets", "wall washers" y luces de paso.

c) Los luminarios "stake mounted" incluyen uplights ajustables, luces de paso y wall washers.

7. ILUMINACION DE JARDINES Y SENDEROS

La iluminación de jardines y senderos tienen luminarios de diferentes tipos montados usualmente en pequeños soportes de menos de 42 pulgadas (1.06 m). Estos luminarios distribuyen la luz hacia abajo para iluminar árboles, caminos, y áreas con pasto. Algunos estilos comunes son el "flower bed light", el "tulip light" y el "pagoda light".

8. ILUMINACION AEREA

La iluminación aérea generalmente se monta arriba de los edificios o de los árboles para iluminar hacia abajo. Un tipo de iluminación aérea se usa para simular la luz de luna dirigiendola por las ramas de un árbol.

9. ILUMINACION ACUATICA

La iluminación acuática se emplea generalmente en albercas y en fuentes, pero se usan variaciones para crear efectos interesantes en manantiales, caidas de agua, jardines de roca, peceras y en muchas más.

VI.3.h.- OTRAS ILUMINACIONES EXTERIORES

Como en la iluminación interior, existen muchos tipos de iluminación exterior, incluyendo algunos tipos especiales diseñados para aplicaciones especiales. Algunos de estos incluyen: Iluminación de deportes, diseñados especialmente para iluminar campos de juego y estadios. Equipo de iluminación marítima, diseñados para soportar los efectos corrosivos del agua salada. Iluminación en la aviación, incluyendo la pista de aterrizaje y diferente equipo de iluminación. Luces de pared, luces de paso y pasamanos para iluminación de escaleras exteriores.

1. REFLECTORES ESPECULARES

a).- La tecnología

La superficie interna de un luminario fluorescente típico tiene una forma simple con un revestimiento de esmalte blanco. Dentro de estos luminarios, la luz efectúa reflexiones múltiples perdiendo intensidad antes de salir del luminario.

En contraste, la forma compleja y alta reflectancia de los reflectores especulares lleva más luz hacia el lugar donde la tarea se realice. De esta forma estos reflectores nos permiten usar menos lámparas y balastros en un sistema de iluminación fluorescente.

La cantidad de luz reflejada y su comportamiento direccional depende de dos características del material del reflector: su reflectancia especular y su reflectancia total.

Un material con alta reflectancia especular tiene un tiene un terminado espejo. Un material con una alta reflectancia total minimiza la cantidad de luz absorbida por la superficie durante la reflexión.

Los reflectores especulares bien diseñados dirigen la luz producida fuera del luminario con un mínimo de reflexiones.

Los reflectores especulares también tienen reflectancia total, y esto significa que durante las pocas reflexiones efectuadas, una mínima cantidad de luz es absorbida por el material.
El material de los reflectores especulares existen en tres categorías.

Film laminado de plata: Un film de poliester es revestido con plata y mezclado con un sustrato de aluminio para producir la alta reflectancia.

Alumino revestido con dieléctrico: Un revestimiento dieléctrico (formado por metales vaporizados y por materiales dieléctricos inorgánicos) es depositado en vacío en un sustrato de aluminio anodizado. El funcionamiento es similar al film de poliester revestido de plata.

Aluminio Pulido: Hecho de un aluminio anodizado altamente especular, estos reflectores tienen un valor de reflectancia menor, pero son menos costosos que los reflectores revestidos con plata o con dieléctrico.

b).- Ventajas

Eficiencia Incrementada. Un reflector especular bien diseñado combinado con delamping puede aumentar la eficiencia del luminario en un 20% ó 30%.

La eficiencia del luminario se define como el porcentaje de luz producido por la lámpara que no es absorbida por el interior del luminario y que realmente lo abandona.

El incremento en la eficiencia se debe a tres factores: a la habilidad del reflector para dirigir más luz fuera del luminario, mejor funcionamiento de la lámpara que normalmente ocurre en los luminarios con delamping (debido a menores temperaturas de operación), y a los efectos de sombra de la lámpara reducidos.

Menor Carga Térmica: Con un menor número de lámparas y con balastros más fríos los costos por carga térmica se reducen considerablemente, aumentando así los ahorros por iluminación al 20%. Los ahorros por la carga térmica varían con el clima, pero son por lo general mayores que los incrementos producidos por el calor porque las cargas térmicas anuales de un edificio son mayores que las cargas por calor.

Apariencia uniforme y reflejo reducido: Los reflectores especulares producen brillantez uniforme similar a la apariencia original del luminario, de tal modo que prevee la tendencia a remplázar
las lámparas faltantes. El reflector puede reducir también la brillantez del luminario cuando se ve con ángulos mayores. Esto reduce el reflejo y mejora el comfort visual dentro del ambiente de trabajo.

c).- Aplicaciones

Los reflectores especulares se usan más comunmente junto con un selectivo delamping. Quitando dos lámparas de un luminario de cuatro, e instalando un reflector especular, la energía utilizada puede redusirse en un 50% con una mantenida salida de luz reducida en un 25% ó 40%.

Esta reducción en la salida de luz puede se apropiada en espacios que necesiten los niveles de luz recomendados. En otro caso la instalación del reflector puede ser suplementada con lámparas con mayor salida y/o con mejores difusores para recobrar la reducción en salida de luz.

Dependiendo de su posición, deberán ser recolocados dentro del luminario las lámparas restantes y sus sockets para maximizar la eficiencia y mejorar la apariencia. Los balastros de encendido rápido que no se usen, deberán ser desconectados. ya que estos seguiran entregando energía después del delamping.

Donde los niveles existentes de luz sean muy bajos, los reflectores especulares pueden aumentar el nivel promedio de luz en un 15% o más, dependiendo de las condiciones existentes de la superficie del esmalte.

Como en cualquier sistema de iluminación la superficie del reflector debe ser limpiada de acuerdo a las instrucciones del fabricante en intervalos regulares, para mantener el nivel óptimode funcionamiento.

También, para mantener los niveles de luz adecuados y ahorrar en los costos de remplazo, el usuario debe establecer un programa de remplazo y limpieza del luminario en intervalos recomendados.

Los reflectores especulares tienden a concentrar la distribución de luz hacia abajo. Aunque esta concentración puede reducir el reflejo y la brillantez, también reduce el haz de luz. Esto puede

reducir la iluminancia a través del espacio y crear areas oscuras en las paredes.
Cuando se evalue el diseño de un reflector, se tiene que checar la libertad de moverlo y de reinstalarlo. También se tiene que ser cauteloso de los llamados diseños estandar que pueden no optimizar la salida de luz. Si se lleva acabo una recolocación o si el reflector está siendo usado cmo parte de una cerca eléctrica, especifique solamente reflectores y accesorios clasificados U.L

Use esta lista cuando evalúe un reflector

a) Prueba de campo del procedimento de diseño.

b) Impacto en el mantenimiento de los niveles de luz y la amplitud del haz.
c) Apariencia uniforme.
d) Necesidad de recolocación de lámparas
e) Clasificación U.L.
f) Requerimientos de codigo locales
g) Garantía en el funcionamiento del reflector.
h) Accesibilidad a los balastros.
i) Selección de nuevas lámparas.
j) Remplazo del difusor/balastro.
k) Desconectar balastros no usados.
l) Remplazo y limpieza por grupos.
m) Cambiar balastros por grupos.

La decisión de usar reflectores especulares debe estar basada en consideraciones económicas, de ingeniería, en calidad de iluminación y estéticas. Para responder todas las preguntas requeridas en la iluminación con reflectores especulares, se necesita la evaluación de todos los componentes del sistema.

Si no puede decidir entre las diferentes alternativas pregunte a un consultor independiente de iluminación.