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DISEÑO Y CONSTRUCCIÓN DE UNA FUENTE DE PODER DE 2 KVA CON SALIDA DE VOLTAJE VARIABLE DE 1000 A 2500 VOLTIOS PARA LA IMPLEMENTACIÓN EN UN CENTRO DE CERTIFICACIÓN DE MÁQUINAS SOLDADORAS.

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Fecha: AGOSTO, 2012

Del contenido del presente trabajo se responsabiliza el autor

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Estimado Ingeniero

Mediante la presente tengo a bien informar que el trabajo investigativo realizado por el señor: **ALVARO PATRICIO AGUIRRE GRANDA**, cuyo tema es: "**DISEÑO Y CONSTRUCCIÓN DE UNA FUENTE DE PODER DE 2 KVA CON SALIDA DE VOLTAJE VARIABLE DE 1000 A 2500 VOLTIOS PARA LA IMPLEMENTACIÓN EN UN CENTRO DE CERTIFICACIÓN DE MÁQUINAS SOLDADORAS**", ha sido elaborado bajo mi supervisión y revisado en todas sus partes, por lo cual autorizo su respectiva presentación.

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Atentamente,

Ing. Néstor Albán M.
DIRECTOR DE TESIS

Dedicatoria

Todo el tiempo, trabajo y esfuerzo se los dedico principalmente a Dios, por darme la oportunidad de vivir y por estar conmigo en cada paso que doy, por fortalecer mi corazón e iluminar mi mente y por haber puesto en mi camino a aquellas personas que han sido mi soporte y compañía durante todo el periodo de estudio.

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Alvaro Patricio Aguirre Granda

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TABLA DE CONTENIDO

Portada i
Hoja de sustentación y aprobación de los integrantes del tribunal ii
Hoja de responsabilidad del autor iii
Hoja de aprobación del director de tesis iv
Dedicatoria v
Agradecimiento vi
Índice vii
Resumen ejecutivo xv
Executive summary xvi

CAPÍTULO I
Introducción, objetivos y justificación

1.1. Introducción 1
1.2. Objetivos 2
1.2.1. Objetivo General 2
1.2.2. Objetivos Específicos 2
1.3. Justificación 2

CAPÍTULO II
Fundamentos teóricos

2.1. Fuente de poder 3
2.2. Transformador 3
2.2.1. Concepto 3
2.2.2. Funcionamiento 4
2.2.3. Tipos de Transformadores 5
2.2.3.1. Según sus aplicaciones 5
2.2.3.1.1. Transformador elevador/reductor de voltaje 5
2.2.3.1.2. Transformadores elevadores 5
2.2.3.1.3. Transformadores variables 5

2.2.3.1.4. Transformador de aislamiento 6
2.2.3.1.5. Transformador de alimentación 6
2.2.3.1.6. Transformador trifásico 7
2.2.3.1.7. Transformador de pulsos 8
2.2.3.1.8. Transformador de línea o Flyback 8
2.2.3.1.9. Transformador diferencial de variación lineal 9
2.2.3.1.10. Transformador con diodo dividido 10
2.2.3.1.11. Transformador de impedancia 10
2.2.3.1.12. Estabilizador de tensión 10
2.2.3.1.13. Transformador híbrido o bobina híbrida 11
2.2.3.1.14. Balun 11
2.2.3.1.15. Transformador electrónico 11
2.2.3.1.16. Transformador de frecuencia variable 12
2.2.3.1.17. Transformadores de medida 12
2.2.3.2. Según su construcción 13
2.2.3.2.1. Autotransformador 13
2.2.3.2.2. Transformador con núcleo toroidal 14
2.2.3.2.3. Transformador de grano orientado 14
2.2.3.2.4. Transformador de núcleo de aire 15
2.2.3.2.5. Transformador de núcleo envolvente 15
2.2.3.2.6. Transformador piezoeléctrico 15
2.3. Autotransformador 16
2.3.1. Concepto 16
2.3.2. Funcionamiento 17
2.3.3. Tipos de construcción 17
2.3.4. Aplicaciones 18
2.3.5. Limitaciones 19

CAPÍTULO III
Parámetros de diseño

3.1. Introducción 21

3.1.1. Potencia nominal ... 22
3.1.2. Corriente máxima ... 22
3.1.3. Voltaje de salida ... 23
3.1.4. Niveles de aislamiento ... 23
3.1.5. Sistemas de seguridad ... 23
3.2. Voltaje de prueba ... 24
3.3. Duración de la aplicación del voltaje de prueba ... 25
3.4. Tipo de transformador para el diseño ... 25

CAPÍTULO IV
Diseño electromecánico

4.1. Generalidades ... 26
4.2. Cálculo de las corrientes en los devanados ... 27
4.3. Cálculo del número de espiras ... 28
4.4. Cálculo de los calibres del conductor ... 31
4.5. Cálculo de la sección transversal del núcleo y sus dimensiones geométricas ... 32
4.6. Cálculo de las dimensiones generales de la bobina y del ancho de ventana de las arcadas del núcleo ... 36
4.6.1. Dimensionado de bobinas ... 36
4.6.1.1. Bobina de baja tensión (B.T.) ... 36
4.6.1.2. Dimensiones del bobinado de alto voltaje (A.T.) ... 42
4.6.2. Determinación del ancho de ventana del núcleo y el peso por arcada ... 48

CAPÍTULO V
Construcción

5.1. Clasificación de las partes de la fuente de poder ... 52
5.1.1. Partes principales ... 52
5.1.2. Partes Auxiliares ... 52
5.2. Descripción breve de la construcción de los transformadores ... 52
5.2.1. Núcleos ... 52

5.2.1.1. Núcleo tipo columna 53
5.2.1.2. Núcleo tipo acorazado 54
5.2.2. Devanados 55
5.3. Construcción del transformador elevador 57
5.3.1. Construcción de las bobinas 57
5.3.2. Armado del núcleo 59
5.3.3. Conexionado 60
5.4. Construcción del gabinete 62
5.5. Montaje de equipos, dispositivos y accesorios 65

CAPÍTULO VI
Análisis económico

6.1. Costos de la parte eléctrica 69
6.2. Costos de la parte mecánica 69
6.3. Costos de transporte y envío 70
6.4. Costos de mano de obra 71
6.5. Costos totales 71

CAPÍTULO VII
Conclusiones y recomendaciones

7.1. Conclusiones 72
7.2. Recomendaciones 73

Bibliografía 74
Anexos 76

ÍNDICE DE FIGURAS

FIGURA 2-1: Transformador tipo seco 4
FIGURA 2-2: Transformador variable 6
FIGURA 2-3: Transformador de aislamiento 6
FIGURA 2-4: Transformador de alimentación 7
FIGURA 2-5: Transformador trifásico 7
FIGURA 2-6: Transformador de pulsos 8
FIGURA 2-7: Transformador flyback 9
FIGURA 2-8: Transformador diferencial de variación lineal 9
FIGURA 2-9: Transformador balun 11
FIGURA 2-10: Transformador electrónico 12
FIGURA 2-11: Transformadores de medida 13
FIGURA 2-12: Autotransformador 14
FIGURA 2-13: Transformador con núcleo toroidal 14
FIGURA 2-14: Transformador de grano orientado 15
FIGURA 3-1: Jaula de faraday 24
FIGURA 4-1: Esquema desarrollado de los devanados (A.T., B.T.) 31
FIGURA 4-2: Relación de aspecto de chapas magnéticas 34
FIGURA 4-3: Corte transversal del devanado de B.T. 38
FIGURA 4-4: Colocación de los collares en el devanado A.T. 42
FIGURA 4-5: Diagrama de corte del conjunto núcleo-bobina 49
FIGURA 5-1: Vista y corte de un núcleo tipo columna 53
FIGURA 5.2: Vista de un núcleo tipo acorazado con indicación de la longitud magnética media 54
FIGURA 5.3: Construcción de las bobinas de B.T. y A.T. 58
FIGURA 5-4: Núcleo armado y listo para el prensado 60
FIGURA 5-5: Aislado de conexiones 61
FIGURA 5-6: Construcción del gabinete 63
FIGURA 5-7: Gabinete con perforaciones para accesorios y ventilación 64
FIGURA 5-8: Gabinete terminado 65
FIGURA 5-9: Instalación de accesorios 66

FIGURA 5-10: Montaje del transformador 66
FIGURA 5-11: Montaje del variac 67
FIGURA 5-12: Instalación de dispositivos de medición y control................................ 68
FIGURA 5-13: Cableado interno de la fuente de poder 68

ÍNDICE DE TABLAS

TABLA 4-1: Voltajes nominales preferenciales 27

TABLA 4-2: Distancias mínimas para aislamientos mayores....................................... 37

TABLA 4-3: Propiedades eléctricas típicas nomex tipo 410 46

TABLA 4-4: Medidas de laminaciones prefabricadas 50

TABLA 6-1: Costos parte eléctrica 69

TABLA 6-2: Costos parte mecánica.. 70

TABLA 6-3: Costos de transporte y envío 70

TABLA 6-4: Costos mano de obra 71

TABLA 6-5: Costos totales 71

ÍNDICE DE ANEXOS

ANEXO 1: Normas NEMA EW-1 y EW-3 77
ANEXO 2: Hojas de procedimientos y recolección de datos para la prueba de alto potencial 153
ANEXO 3: Características de los alambres MAGNETO redondos 159
ANEXO 4: Conectores prensa estopa 161
ANEXO 5: Características del cable para bujía 163
ANEXO 6: Protocolo de pruebas del transformador elevador 165
ANEXO 7: Tabulación de mediciones al transformador elevador y representación en gráficas 167
ANEXO 8: Planos de construcción del gabinete de la fuente de poder 170

RESUMEN EJECUTIVO

La prueba de alto potencial es una etapa fundamental en el proceso de certificación de máquinas soldadoras, pues de él depende en gran parte la calidad de la certificación, hasta la actualidad se realizan este tipo de pruebas en el extranjero, siendo Brasil el país más cercano en el cual existe uno de estos centros.

Por este motivo se optó por realizar el presente trabajo de investigación y desarrollo para la fabricación de la fuente de poder.

La fuente de poder se diseñó en base a los datos técnicos consultados en la tesis "Estudio para la implantación de un Centro de Certificación de Máquinas Soldadoras" desarrollado por el Ing. Ricardo Aguirre, para la carrera de Ingeniería Mecánica de la Escuela Politécnica Nacional.

Primeramente se procedió a realizar los cálculos pertinentes para el diseño y construcción del transformador elevador requerido para la fuente de poder, obtenidos los resultados de los cálculos para los devanados y el núcleo ferromagnético, se construyen las bobinas y la selección de las laminaciones prefabricadas.

Con el transformador construido en su totalidad se procedió al diseño y construcción del gabinete requerido, para esto se utilizarán las medidas totales del transformador y el variac, previamente importado, dejando un espacio de seguridad entre los bornes de alta tensión y la carcasa, sirviendo también para la ventilación del equipo.

Habiendo construido la carcasa en su totalidad se realizó el montaje de los equipos, dispositivos y accesorios, obteniendo como resultado una fuente de poder capaz de manejar voltajes desde 0 hasta 2500 voltios.

EXECUTIVE SUMMARY

The high potential test is a critical step in the process of certifying welding machines, given that on it, the quality of the certification depends largely. Up to date, these tests have to be performed abroad, being Brazil the closest country in which there is such a center.

For this reason it was decided to conduct this research and development for the manufacture of the power supply.

The power supply was designed based on technical data consulted in the thesis "Study for the establishment of a Certification Center for Welding Machines" developed by Mr. Ricardo Aguirre (B.Sc. ME), for the Mechanical Engineering school of the “Escuela Politécnica Nacional” (National Polytechnic School).

First, the calculations relevant for the design and construction of the transformer required for the power supply were performed. Once the results were obtained from the calculations of the ferromagnetic core and windings, the coils were constructed and the prefabricated laminations were selected.

With the transformer entirely built, the design and construction of the required cabinet were performed. For this, the total size of transformer and variac (previously imported) was used, leaving a safety gap between the high voltage terminals and the case, which was also used for the equipment’s ventilation.

Having constructed the whole case, it was performed the assembly of all the equipment, devices, and accessories, resulting in a power supply capable of handling voltages from 0 to 2500 volts.

CAPÍTULO I

INTRODUCCIÓN, OBJETIVOS Y JUSTIFICACIÓN

1.1. Introducción

Este proyecto se lo ha construido por la necesidad que tiene el país para certificar la calidad de máquinas soldadoras, en base a estándares NEMA, los cuales garanticen la calidad de la certificación y que esta cuente con la aceptación del sector industrial.

La fuente de poder es necesaria para realizar la prueba de alto voltaje a las máquinas soldadoras, sin la cual no se podría realizar una completa certificación, por ende surge la importancia de obtener dicha fuente.

En el Ecuador, el número de empresas que necesitan de una certificación para sus máquinas soldadoras han ido incrementándose cada vez más, debido a que en el país no existen empresas que realicen este tipo de actividad y al momento de realizar una certificación en el extranjero los costos por traslado serían demasiado elevados. Es por esta razón que se desea crear una de las partes primordiales para la creación de una empresa certificadora de maquinas soldadoras, como es la fuente de poder de 2 KVA.

La tesis se basa en el diseño y construcción de la fuente de poder de 2 KVA con la cual se podrá realizar la prueba de alto voltaje para la certificación de las máquinas soldadoras, teniendo en cuenta los requisitos que exigen los estándares EW-1 y EW-3 de la NEMA, y una vez que se implemente en el centro de certificación, ayudará al sector industrial en la disminución de los costos que representa realizar este tipo de ensayos debido a que no necesitarán enviar sus máquinas al extranjero para obtener una certificación de calidad.

1.2. Objetivos

1.2.1. Objetivo General

Diseñar y construir la fuente de poder de 2 KVA con salida de voltaje variable para realizar la prueba de alto voltaje en máquinas soldadoras y brindar un servicio completo de un Centro de Certificación de máquinas soldadoras.

1.2.2. Objetivos Específicos

- Realizar un estudio de las diferentes fuentes de poder que se emplean para los procesos de soldadura.
- Establecer cuáles son los voltajes de prueba y requisitos que deben cumplir las máquinas soldadoras para que puedan ser certificadas.
- Establecer los niveles de voltaje de salida requeridos para determinar en parte el diseño de la fuente de poder.
- Calcular el costo aproximado de la construcción de una fuente de poder de 2 KVA con salida de voltaje variable de 1000 a 2500 voltios.

1.3. Justificación

La fuente de poder de 2 KVA con salida de voltaje variable es necesaria para la realización de pruebas de alto potencial en máquinas soldadoras, y dado que para otorgar una certificación, en base a normas internacionales de calidad, a dichas máquinas, es indispensable la realización de estas pruebas, se procederá con el diseño y construcción de la fuente de poder.

CAPÍTULO II

FUNDAMENTOS TEÓRICOS

2.1. Fuente de poder

La fuente de poder, fuente de alimentación o fuente de energía es una fuente eléctrica, un artefacto activo que puede proporcionar corriente eléctrica gracias a la generación de una diferencia de potencial entre sus bornes. Se diseña a partir de una fuente ideal, que es un concepto utilizado en la teoría de circuitos para analizar el comportamiento de los componentes eléctricos y electrónicos de los circuitos reales.

2.2. Transformador

2.2.1. Concepto

Se denomina transformador a un dispositivo eléctrico que permite aumentar o disminuir la tensión en un circuito eléctrico de corriente alterna, manteniendo la frecuencia. La potencia que ingresa al equipo, en el caso de un transformador ideal (esto es, sin pérdidas), es igual a la que se obtiene a la salida. Las máquinas reales presentan un pequeño porcentaje de pérdidas, dependiendo de su diseño, tamaño, etc.

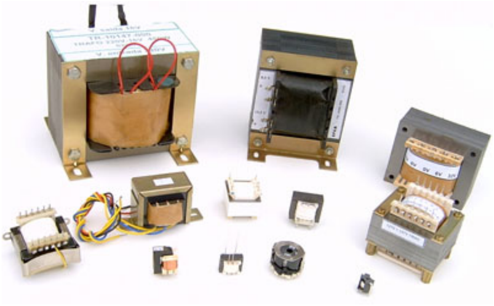
“Un transformador es un dispositivo que cambia la potencia eléctrica alterna con un nivel de voltaje a potencia eléctrica alterna con otro nivel de voltaje mediante la acción de un campo magnético. Consta de dos o más bobinas de alambre conductor enrolladas alrededor de un núcleo ferromagnético común. Estas bobinas (normalmente) no están conectadas en forma directa. La única conexión entre las bobinas es el flujo magnético común que se encuentra dentro del núcleo.”[1]

---

[1] CHAPMAN Stephen J., Máquinas Eléctricas, Cuarta Edición, 2005, Pág. 65.

Los transformadores son dispositivos basados en el fenómeno de la inducción electromagnética y están constituidos, en su forma más simple, por dos bobinas devanadas sobre un núcleo cerrado de hierro dulce o hierro silicio. Las bobinas o devanados se denominan primario y secundario según correspondan a la entrada o salida del sistema, respectivamente. También existen transformadores con más devanados; en este caso, puede existir un devanado "terciario", de menor tensión que el secundario.

FIGURA 2-1
TRANSFORMADOR TIPO SECO



Fuente: www.codisin.com/productos/automatizacion/equipos-cuadro-electrico/transformadores.html
Elaborado por: Alvaro Aguirre / 2011

2.2.2. Funcionamiento

Si se aplica una fuerza electromotriz alterna en el devanado primario, las variaciones de intensidad y sentido de la corriente alterna crearán un campo magnético variable dependiendo de la frecuencia de la corriente. Este campo magnético variable originará, por inducción electromagnética, la aparición de una fuerza electromotriz en los extremos del devanado secundario.

2.2.3. Tipos de Transformadores

2.2.3.1. Según sus aplicaciones

2.2.3.1.1. Transformador elevador/reductor de voltaje

Son empleados por empresas transportadoras eléctricas en las subestaciones de la red de transporte de energía eléctrica, con el fin de disminuir las pérdidas por efecto Joule. Debido a la resistencia de los conductores, conviene transportar la energía eléctrica a tensiones elevadas, lo que origina la necesidad de reducir nuevamente dichas tensiones para adaptarlas a las de utilización.

2.2.3.1.2. Transformadores elevadores

Este tipo de transformadores nos permiten, como su nombre lo dice, elevar la tensión de salida con respecto a la tensión de entrada. Esto quiere decir que la relación de transformación de estos transformadores es menor a uno.

2.2.3.1.3. Transformadores variables

También llamados "Variacs", toman una línea de voltaje fijo (en la entrada) y proveen de voltaje de salida variable ajustable, dentro de dos valores.

FIGURA 2-2
TRANSFORMADOR VARIABLE

Fuente: electronicapascual.com/blog/?p=98
Elaborado por: Alvaro Aguirre / 2011

2.2.3.1.4. Transformador de aislamiento

Proporciona aislamiento galvánico entre el primario y el secundario, de manera que consigue una alimentación o señal "flotante". Suele tener una relación 1:1. Se utiliza principalmente como medida de protección, en equipos que trabajan directamente con la tensión de red. También para acoplar señales procedentes de sensores lejanos, en equipos de electromedicina y allí donde se necesitan tensiones flotantes entre sí.

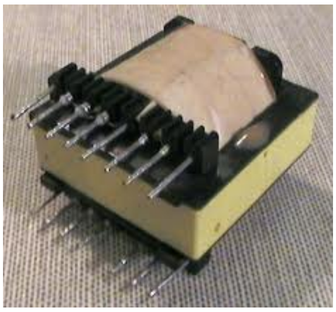
FIGURA 2-3
TRANSFORMADOR DE AISLAMIENTO

Fuente: www.pe.all.biz/g10729/
Elaborado por: Alvaro Aguirre / 2011

2.2.3.1.5. Transformador de alimentación

Pueden tener una o varias bobinas secundarias y proporcionan las tensiones necesarias para el funcionamiento del equipo. A veces incorpora un fusible que corta su circuito primario cuando el transformador alcanza una temperatura excesiva, evitando que éste se queme, con la emisión de humos y gases que conlleva el riesgo de incendio. Estos fusibles no suelen ser reemplazables, de modo que hay que sustituir todo el transformador.

FIGURA 2-4
TRANSFORMADOR DE ALIMENTACIÓN



Fuente: www.jmas-electronica.com/?p=136
Elaborado por: Alvaro Aguirre / 2011

2.2.3.1.6. Transformador trifásico

Tienen tres bobinados en su primario y tres en su secundario. Pueden adoptar conexiones de estrella (Y) (con hilo de neutro o no) o delta (Δ) y las combinaciones entre ellas: Δ-Δ, Δ-Y, Y-Δ y Y-Y. Hay que tener en cuenta que aún con relaciones 1:1, al pasar de Δ a Y o viceversa, las tensiones de fase varían.

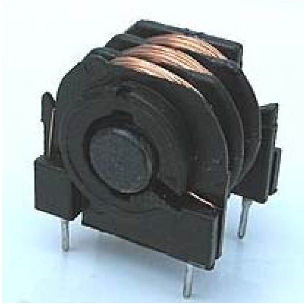
FIGURA 2-5
TRANSFORMADOR TRIFÁSICO

Fuente: es.wikipedia.org/wiki/Transformador
Elaborado por: Alvaro Aguirre / 2011

2.2.3.1.7. Transformador de pulsos

Es un tipo especial de transformador con respuesta muy rápida (baja autoinducción) destinado a funcionar en régimen de pulsos y además de muy versátil utilidad en cuanto al control de tensión 220 V.

FIGURA 2-6
TRANSFORMADOR DE PULSOS



Fuente: www.directindustry.es/fabricante-industrial/transformador-pulsos-80809.html
Elaborado por: Alvaro Aguirre / 2011

2.2.3.1.8. Transformador de línea o Flyback

Es un caso particular de transformador de pulsos. Se emplea en los televisores con TRC (CRT) para generar la alta tensión y la corriente para las bobinas de deflexión horizontal. Suelen ser pequeños y económicos. Además suele proporcionar otras tensiones para el tubo (foco, filamento, etc.). Además de poseer una respuesta en frecuencia más alta que muchos transformadores, tiene la característica de mantener diferentes niveles de potencia de salida debido a sus diferentes arreglos entre sus bobinados secundarios.

FIGURA 2-7
TRANSFORMADOR FLYBACK

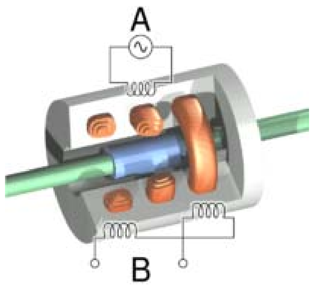
Fuente: www.yoreparo.com/foros/de_todo/543300_0.html
Elaborado por: Alvaro Aguirre / 2011

2.2.3.1.9. Transformador diferencial de variación lineal

El transformador diferencial de variación lineal (LVDT según sus siglas en inglés) es un tipo de transformador eléctrico utilizado para medir desplazamientos lineales. El transformador posee tres bobinas dispuestas extremo con extremo alrededor de un tubo. La bobina central es el devanado primario y las externas son los secundarios. Un centro ferromagnético de forma cilíndrica, sujeto al objeto cuya posición desea ser medida, se desliza con respecto al eje del tubo.

Los LVDT son usados para la realimentación de posición en servomecanismos y para la medición automática en herramientas y muchos otros usos industriales y científicos.

FIGURA 2-8
TRANSFORMADOR DIFERENCIAL DE VARIACIÓN LINEAL



Fuente: es.wikipedia.org/wiki/Transformador
Elaborado por: Alvaro Aguirre / 2011

2.2.3.1.10. Transformador con diodo dividido

Es un tipo de transformador de línea que incorpora el diodo rectificador para proporcionar la tensión continua de MAT directamente al tubo. Se llama diodo dividido porque está formado por varios diodos más pequeños repartidos por el bobinado y conectados en serie, de modo que cada diodo sólo tiene que soportar una tensión inversa relativamente baja. La salida del transformador va directamente al ánodo del tubo, sin diodo ni triplicador.

2.2.3.1.11. Transformador de impedancia

Este tipo de transformador se emplea para adaptar antenas y líneas de transmisión (tarjetas de red, teléfonos, etc.) y era imprescindible en los amplificadores de válvulas para adaptar la alta impedancia de los tubos a la baja de los altavoces.

Si se coloca en el secundario una impedancia de valor *Z*, y llamamos *n* a $\frac{N_s}{N_p}$, como $I_s = -\frac{I_p}{n}$ y $E_s = E_p \cdot n$, la impedancia vista desde el primario será $\frac{E_p}{I_p} = -\frac{E_s}{n^2 I_s} = \frac{Z}{n^2}$. Así, hemos conseguido transformar una impedancia de valor *Z* en otra de $\frac{Z}{n^2}$. Colocando el transformador al revés, lo que hacemos es elevar la impedancia en un factor n^2.

2.2.3.1.12. Estabilizador de tensión

Es un tipo especial de transformador en el que el núcleo se satura cuando la tensión en el primario excede su valor nominal. Entonces, las variaciones de tensión en el secundario quedan limitadas. Tenía una labor de protección de los equipos frente a fluctuaciones de la red. Este tipo de transformador ha caído en desuso con el desarrollo de los reguladores de tensión electrónicos, debido a su volumen, peso, precio y baja eficiencia energética.

2.2.3.1.13. Transformador híbrido o bobina híbrida

Es un transformador que funciona como una híbrida. De aplicación en los teléfonos, tarjetas de red, etc.

2.2.3.1.14. Balun

Es muy utilizado como balun para transformar líneas equilibradas en no equilibradas y viceversa. La línea se equilibra conectando a masa la toma intermedia del secundario del transformador.

FIGURA 2-9
TRANSFORMADOR BALUN

Fuente: radioallimite.blogspot.com/2011_03_01_archive.html
Elaborado por: Alvaro Aguirre / 2011

2.2.3.1.15. Transformador electrónico

Está compuesto por un circuito electrónico que eleva la frecuencia de la corriente eléctrica que alimenta al transformador, de esta manera es posible reducir drásticamente su tamaño. También pueden formar parte de circuitos más complejos que mantienen la tensión de salida en un valor prefijado sin importar la variación en la entrada, llamados fuente conmutada.

FIGURA 2-10
TRANSFORMADOR ELECTRÓNICO

Fuente: www.unioviedo.es
Elaborado por: Alvaro Aguirre / 2011

2.2.3.1.16. Transformador de frecuencia variable

Son pequeños transformadores de núcleo de hierro, que funcionan en la banda de audiofrecuencias. Se utilizan a menudo como dispositivos de acoplamiento en circuitos electrónicos para comunicaciones, medidas y control.

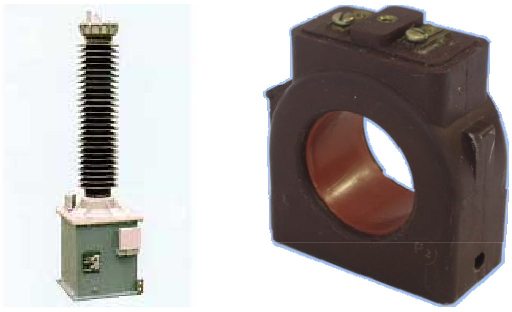
2.2.3.1.17. Transformadores de medida

Entre los transformadores con fines especiales, los más importantes son los transformadores de medida para instalar instrumentos, contadores y relés protectores en circuitos de alta tensión o de elevada corriente. Los transformadores de medida aíslan los circuitos de medida o de relés, permitiendo una mayor normalización en la construcción de contadores, instrumentos y relés.

"Estos pueden ser de tensión o de intensidad. Su función fundamental consiste en aislar y adecuar los valores de las características eléctricas a las necesidades que se presenten en cada caso, aprovechando las características básicas de los transformadores.

Aíslan de las altas tensiones, creando una separación física entre circuitos. Adecúan los valores de tensión e intensidad, en función de su relación de transformación, a las necesidades de uso. La adecuación de los valores de tensión e intensidad hacen posible el uso de aparatos de medidas de bajas tensiones e intensidades en redes de alta tensión y de elevados consumos."[2]

FIGURA 2-11
TRANSFORMADORES DE MEDIDA



Fuente: html.rincondelvago.com/transformadores-medida.html
Elaborado por: Alvaro Aguirre / 2011

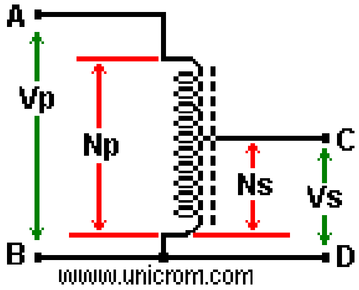
2.2.3.2. Según su construcción

2.2.3.2.1. Autotransformador

El primario y el secundario del transformador están conectados en serie, constituyendo un bobinado único. Pesa menos y es más barato que un transformador y por ello se emplea habitualmente para convertir 220 V a 125 V y viceversa y en otras aplicaciones similares. Tiene el inconveniente de no proporcionar aislamiento galvánico entre el primario y el secundario.

[2] MANZANO Juan José, Mantenimiento de máquinas eléctricas, Cuarta Edición, 2002, Pág. 31.

FIGURA 2-12
AUTOTRANSFORMADOR

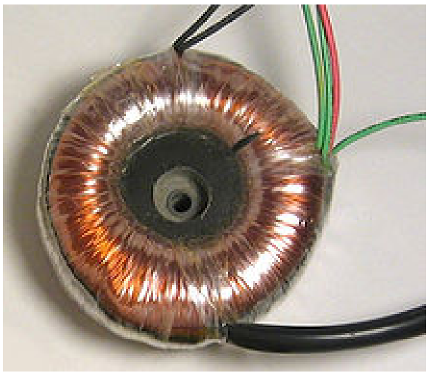


Fuente: www.unicrom.com/Tut_autotransformador.asp
Elaborado por: Alvaro Aguirre / 2011

2.2.3.2.2. Transformador con núcleo toroidal

El núcleo consiste en un anillo, normalmente de compuestos artificiales de ferrita, sobre el que se bobinan el primario y el secundario. Son más voluminosos, pero el flujo magnético queda confinado en el núcleo, teniendo flujos de dispersión muy reducidos y bajas pérdidas por corrientes de Foucault.

FIGURA 2-13
TRANSFORMADOR CON NÚCLEO TOROIDAL



Fuente: es.wikipedia.org/wiki/Transformador
Elaborado por: Alvaro Aguirre / 2011

2.2.3.2.3. Transformador de grano orientado

El núcleo está formado por una chapa de hierro de grano orientado, enrollada sobre sí misma, siempre en el mismo sentido, en lugar de las láminas de hierro dulce separadas habituales. Presenta pérdidas muy reducidas pero es caro. La chapa de hierro de grano orientado puede ser también utilizada en transformadores orientados (chapa en E), reduciendo sus pérdidas.

FIGURA 2-14
TRANSFORMADOR DE GRANO ORIENTADO

Fuente: es.wikipedia.org/wiki/Transformador
Elaborado por: Alvaro Aguirre / 2011

2.2.3.2.4. Transformador de núcleo de aire

En aplicaciones de alta frecuencia se emplean bobinados sobre un carrete sin núcleo o con un pequeño cilindro de ferrita que se introduce más o menos en el carrete, para ajustar su inductancia.

2.2.3.2.5. Transformador de núcleo envolvente

Están provistos de núcleos de ferrita divididos en dos mitades que, como una concha, envuelven los bobinados. Evitan los flujos de dispersión.

2.2.3.2.6. Transformador piezoeléctrico

Para ciertas aplicaciones han aparecido en el mercado transformadores que no están basados en el flujo magnético para transportar la energía entre el primario y el secundario, sino que se emplean vibraciones mecánicas en un cristal piezoeléctrico.

Tienen la ventaja de ser muy planos y funcionar bien a frecuencias elevadas. Se usan en algunos convertidores de tensión para alimentar los fluorescentes del backlight de ordenadores portátiles.

2.3. Autotransformador

2.3.1. Concepto

"El autotransformador es un transformador especial formado por un devanado continuo, que se utiliza a la vez como primario y secundario, por lo que las tensiones de alimentación y salida no van aisladas entre sí. A diferencia del transformador de dos devanados, un autotransformador transfiere energía entre los dos circuitos, **en parte por acoplamiento magnético y en parte por conexión eléctrica directa.**"[3]

Un autotransformador es una máquina eléctrica, de construcción y características similares a las de un transformador, pero que a diferencia de éste, sólo posee un único devanado alrededor del núcleo. Dicho devanado debe tener al menos tres puntos de conexión eléctrica, llamados tomas. La fuente de tensión y la carga se conectan a dos de las tomas, mientras que una toma (la del extremo del devanado) es una conexión común a ambos circuitos eléctricos (fuente y carga). Cada toma corresponde a un voltaje diferente de la fuente (o de la carga, dependiendo del caso).

En un autotransformador, la porción común (llamada por ello "devanado *común*") del devanado único actúa como parte tanto del devanado "primario" como del "secundario". La porción restante del devanado recibe el nombre de "devanado *serie*" y es la que proporciona la diferencia de voltaje entre ambos circuitos, mediante la adición en serie (de allí su nombre) con el voltaje del devanado común.

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[3] MORA Jesús Fraile, Máquinas Eléctricas, Sexta Edición, 2008, Pág. 258.

2.3.2. Funcionamiento

Al igual que los transformadores, los autotransformadores funcionan basados en el principio de campos magnéticos variantes en el tiempo, por lo que tampoco pueden ser utilizados en circuitos de corriente continua.

La transferencia de potencia entre dos circuitos conectados a un autotransformador ocurre a través de dos fenómenos: el acoplamiento magnético (como en un transformador común) y la conexión galvánica entre los dos circuitos (a través de la toma común). Por esta razón, un autotransformador resulta en un aparato más compacto (y a menudo más económico) que un transformador de la misma potencia y voltajes nominales. De igual manera, un transformador incrementa su capacidad de transferir potencia al ser conectado como autotransformador.

La relación de transformación de un autotransformador es la relación entre el número de vueltas del devanado completo (serie + común) y el número de vueltas del devanado común. Por ejemplo, con una toma en la mitad del devanado se puede obtener un voltaje de salida (en el devanado "común") igual a la mitad del de la fuente (o viceversa). Dependiendo de la aplicación, la porción del devanado que se utiliza sólo para el circuito de alta tensión se puede fabricar con alambre de menor calibre (puesto que requiere menos corriente) que la porción del devanado común a ambos circuitos; de esta manera la máquina resultante es aún más económica.

2.3.3. Tipos de construcción

Existen autotransformadores con varias tomas en el secundario y por lo tanto, con varias relaciones de transformación. De la misma manera que los transformadores, los autotransformadores también pueden equiparse con cambiadores de toma automáticos y utilizarlos en sistemas de transmisión y distribución para regular la tensión de la red eléctrica.

Con la incorporación de varias tomas, es posible obtener más de un valor para el voltaje secundario e incluso es posible obtener voltajes ligeramente mayores a los de la fuente, para ello, el devanado debe construirse para que su voltaje nominal sea ligeramente mayor que el del lado fijo o primario. También existen autotransformadores en los que la toma secundaria se logra a través de una escobilla deslizante, permitiendo una gama continua de voltajes secundarios que van desde cero hasta el voltaje de la fuente. Este último diseño se comercializó en Estados Unidos bajo el nombre genérico de *Variac* y en la práctica funciona como una fuente de corriente alterna regulable en voltaje.

2.3.4. Aplicaciones

Los autotransformadores se utilizan a menudo en sistemas eléctricos de potencia, para interconectar circuitos que funcionan a voltajes diferentes, pero en una relación cercana a 2:1 (por ejemplo, 400 kV / 230 kV ó 138 kV / 66 kV). En la industria, se utilizan para conectar maquinaria fabricada para tensiones nominales diferentes a la de la fuente de alimentación (por ejemplo, motores de 480 V conectados a una alimentación de 600 V). Se utilizan también para conectar aparatos, electrodomésticos y cargas menores en cualquiera de las dos alimentaciones más comunes a nivel mundial (100-130 V a 200-250 V).

En sistemas de distribución rural, donde las distancias son largas, se pueden utilizar autotransformadores especiales con relaciones alrededor de 1:1, aprovechando la multiplicidad de tomas para variar el voltaje de alimentación y así compensar las apreciables caídas de tensión en los extremos de la línea.

Se utilizan autotransformadores también como método de arranque suave para motores de inducción tipo jaula de ardilla, los cuales se caracterizan por demandar una alta corriente durante el arranque. Si se alimenta el motor conectándolo a la toma menor de un autotransformador, el voltaje reducido de la alimentación resultará en una menor corriente de arranque y por lo tanto en condiciones más seguras de operación, tanto para el motor como para la instalación eléctrica. Una vez que el motor ha alcanzado suficiente velocidad, se puede ir aumentando el voltaje de alimentación (en tantos pasos como tomas posea el autotransformador) gradualmente, hasta llegar al voltaje de la red (cuando la relación de tomas es 1:1).

En sistemas ferroviarios de Alta velocidad existen métodos de alimentación duales tales como el conocido como 2x25 kV. En este, los transformadores de las subestaciones alimentan a +25 kV a la catenaria, a -25 kV (en realidad 25 kV desfasados 180º) al feeder o alimentador negativo y con la toma intermedia o neutro puesta al carril. Cada cierto tiempo, 10 km típicamente, se conectan autotransformadores con 50 kV en el primario (entre catenaria y feeder negativo) y 25 kV en el secundario (entre feeder negativo y carril). De esta manera, la carga (trenes) se encuentra alimentada a 25 kV entre catenaria y carril pero la energía se transporta a 50 kV, reduciendo las pérdidas.

2.3.5. Limitaciones

Una falla en el aislamiento de los devanados de un autotransformador puede producir que la carga quede expuesta a recibir plena tensión (la de la fuente). Se debe tener en cuenta esta situación al decidir utilizar un autotransformador para una determinada aplicación.

Las ventajas en ahorro de material (tanto en los devanados como en el núcleo) tienen una limitación física, que en la práctica es una relación de voltajes de 3:1. Para relaciones de tensión mayores a ésta, o bien el transformador convencional de dos devanados es más compacto y económico, o bien resulta imposible construir el autotransformador.

En sistemas de transmisión de energía eléctrica, los autotransformadores tienen la desventaja de no filtrar el contenido armónico de las corrientes y de actuar como otra fuente de corrientes de falla a tierra. Sin embargo, existe una conexión especial -llamada "conexión en zig-zag"- que se emplea en sistemas trifásicos para abrir un camino de retorno a la corriente de tierra que de otra manera no sería posible lograr, manteniendo la referencia de tierra.

CAPÍTULO III

PARÁMETROS DE DISEÑO

3.1. Introducción

Cuando se propone un proyecto de diseño mecánico o construcción de cualquier sistema, uno de los primeros pasos que hay que dar es la determinación de las especificaciones iniciales, es decir, los parámetros de diseño que tiene que cumplir el dispositivo para satisfacer las necesidades establecidas.

Para la determinación de las especificaciones iniciales es necesario conocer el problema, y en lo posible, saber cuáles son las soluciones que tradicionalmente se han dado.

Para la construcción de este proyecto, los parámetros que se debe controlar son los siguientes:

- Potencia nominal
- Corriente máxima
- Voltaje de salida
- Niveles de aislamiento
- Sistemas de seguridad

Para cumplir con los requerimientos del centro de certificación de máquinas soldadoras se necesita poner especial énfasis en el voltaje de salida del equipo a construir, puesto que éste será el determinante para una correcta prueba de alto potencial, sin dejar de lado los parámetros de potencia y corriente, que aunque son pequeños y no afectan en dicha prueba, intervienen de manera directa en el diseño del transformador, adicionalmente a esto debemos calcular los niveles de aislamiento en el circuito de salida ya que se trabajará con voltajes de media tensión que van desde 1000 hasta 2500 voltios, requiriendo así implementar sistemas de seguridad para evitar posibles accidentes.

3.1.1. Potencia nominal

La potencia nominal es la potencia máxima continua que demanda una máquina o equipo en condiciones de uso normales; esto quiere decir que el equipo está diseñado para soportar esa cantidad de potencia, sin embargo debido a fluctuaciones en la corriente, al uso excesivo o continuo, o en situaciones de uso distintas a las del diseño, la potencia real puede diferir de la nominal, siendo más alta o más baja.

El transformador que se construirá para el Centro de Certificación de Máquinas Soldadoras deberá tener una potencia nominal de 2 KVA, dado que no se necesita una corriente elevada para la prueba a realizar.

3.1.2. Corriente máxima

La corriente máxima (también conocida como corriente admisible y, sobre todo en los países hispanoamericanos, como ampacidad, tomado del inglés ampacity) es la máxima intensidad de corriente que puede circular de manera continua por un conductor eléctrico sin que éste sufra daños.

Esta corriente varía según las condiciones en que se encuentre el conductor, su sección, el material de su aislamiento y de la cantidad de conductores agrupados.

Las corrientes máximas para las cuales está diseñado el transformador son de 9,1 A en el bobinado de baja tensión y 0,8 A en el bobinado de alta tensión.

3.1.3. Voltaje de salida

Este es con seguridad el parámetro más importante a controlar, del cual va a depender que se cumpla en su totalidad y de forma acertada, todo el proceso de la prueba de alto potencial en los distintos componentes de las máquinas soldadoras.

El valor del voltaje de salida se regula de modo manual mediante un VARIAC, realizando las mediciones en el lado de baja tensión del transformador, obteniendo el valor de salida mediante la relación de transformación, que para nuestro equipo es de 1:11,36.

3.1.4. Niveles de aislamiento

Los niveles de aislamiento para los componentes y circuitos del equipo están calculados en base a los voltajes soportados en cada uno de estos, considerando para la construcción de dicha fuente los materiales existentes en el mercado local y tomando en cuenta el nivel de aislamiento propio de cada uno.

Por esta razón se utilizarán en la construcción de la fuente de poder los materiales cuyo nivel de aislamiento mínimo sea igual o superior al valor obtenido en los cálculos realizados para el diseño del equipo.

3.1.5. Sistemas de seguridad

Puesto que la fuente de poder a construir no es de gran potencia, y se manejarán niveles de corriente relativamente bajos en el circuito de salida, se implementará una protección termo-magnética en el circuito de entrada, manteniendo así el equipo protegido ante cortocircuitos y sobrecargas que se pudiesen producir.

Adicionalmente a esto, dado que el equipo maneja niveles de voltaje considerables en el circuito de salida, se optó por realizar una jaula de faraday en el centro de certificación donde esta entrará en operación, colocando dentro de dicha jaula el elemento al cual se le realizará la prueba de alto potencial, para de esta manera salvaguardar la integridad física del personal que labora en este centro de certificación.

FIGURA 3-1
JAULA DE FARADAY

Fuente: elbustodepalas.blogspot.com/2010/06/la-jaula-de-faraday-o-de-porque-los.html
Elaborado por: Alvaro Aguirre / 2011

3.2. Voltaje de prueba

El voltaje RMS de prueba de corriente alterna para todas las fuentes de poder para soldadura nuevas debe ser 1000 voltios más el doble del voltaje nominal del circuito bajo prueba. La frecuencia de todos los voltajes de prueba deben ser 50 o 60 Hz, y la forma de la onda debe ser esencialmente sinusoidal.

No es recomendado repetir la aplicación del voltaje de prueba de alto potencial. Si es necesario someter a la fuente de poder a una prueba de alto potencial subsecuente, el voltaje de prueba debe ser 85% del voltaje de prueba para una fuente de poder nueva.

3.3. Duración de la aplicación del voltaje de prueba

El voltaje de prueba para las fuentes de poder debe ser aplicado continuamente por un periodo de un minuto excepto para los periodos de tiempo alternativos especificados para pruebas en líneas de producción.

3.4. Tipo de transformador para el diseño

Como se anotó en el capítulo anterior tenemos una gran variedad de transformadores, los cuales son utilizados para diversos fines, pero en función del equipo que necesitamos desarrollar, el nivel de potencia a manipular, las facilidades de manejo y demás bondades, hemos elegido dos de estos, los cuales son el transformador elevador y el transformador variable.

CAPÍTULO IV

DISEÑO ELECTROMECÁNICO

4.1. Generalidades

Los cálculos de un transformador son las especificaciones técnicas en cuanto a construcción se refiere, cada transformador tiene un determinado valor de cálculo pero en cuanto a procedimiento y desarrollo es el mismo.

Los datos que se utilizan para el cálculo del diseño de un transformador son generalmente: voltajes del primario, voltajes del secundario tanto en las líneas como en las fases con carga, para cos φ = 1 o 0,8 y su capacidad en KVA, así también no se puede dejar de lado los parámetros eléctricos tales como: porcentaje de impedancia (%Z), porcentaje de la corriente de excitación (%I0), las pérdidas en vacío (PFe), las pérdidas de carga (PCu) y la eficiencia.

A continuación se procederá a diseñar un transformador tipo seco de 2 KVA, con doble voltaje nominal de entrada de 220 y 240 voltios, y un voltaje de salida de 2500 voltios, 60Hz, 75ºC.

TABLA 4-1
VOLTAJES NOMINALES PREFERENCIALES

Clase de aislamiento (KV)	Voltajes (V)
1,2	120/20 240/120 220/127 40/254 480/277
5	4160
8,7	7620
15	13200 13800
25	19050 20000 22860 23000
34,5	33000 34500
46	46000
69	66000

Fuente: PÉREZ Pedro Avelino, Transformadores de distribución, 2ª Edición, 2001
Elaborado por: Alvaro Aguirre / 2011

4.2. Cálculo de las corrientes en los devanados

Primeramente se empezará por calcular las corrientes en el primario de nuestro transformador.

$$I = \frac{S}{V} \tag{4.1}$$

$$Ip_1 = \frac{S}{Vp_1}$$

$$Ip_1 = \frac{2\ KVA}{0{,}220\ KV}$$

$$Ip_1 = 9{,}09\ A$$

$$Ip_2 = \frac{S}{Vp_2}$$

$$Ip_2 = \frac{2\ KVA}{0{,}240\ KV}$$

$$Ip_2 = 8{,}33\ A$$

Para el secundario la tensión nominal es 2500 V

$$Is = \frac{S}{Vs}$$

$$Is = \frac{2\ KVA}{2{,}5\ KV}$$

$$Is = 0{,}8\ A$$

4.3. Cálculo del número de espiras

Se puede determinar el número inicial de espiras mediante dos métodos que son:

- A partir de un diseño similar a disposición.
- Mediante la determinación empírica de la relación *Ve = Volts / espira*, en cuyo caso se utiliza la siguiente formula.

$$Ve = K\sqrt{S} \tag{4.2}$$

Donde:

K = constante = 0,87

S = Potencia del transformador en KVA

Por lo tanto:

$$Ve = 0{,}87\,\sqrt{2}$$

$$Ve = 1{,}23\ V/esp$$

Una vez calculado *Ve* se procede a calcular el número de espiras del devanado primario, para lo cual se debe reemplazar los datos en la siguiente ecuación:

Para la sección del devanado a 220 V tenemos:

$$N = \frac{V}{Ve} \tag{4.3}$$

$$N_1 = \frac{Vp_1}{Ve}$$

$$N_1 = \frac{220\ V}{1{,}23\ V/esp}$$

$$N_1 = 178{,}81\ esp$$

Para la sección del devanado a 240 V tenemos:

$$N_2 = \frac{Vp_2}{Ve}$$

$$N_2 = \frac{240\ V}{1{,}23\ V/esp}$$

$$N_2 = 195{,}06\ esp$$

Por razones de elaboración se toman números enteros de cualquiera de las dos secciones del devanado primario, para nuestro caso tomaremos el dato de N_1, el número entero próximo es *179 espiras*, con este dato se recalcula *Ve*, para obtener las espiras del devanado secundario:

$$Ve = \frac{220\ V}{179\ esp} \tag{4.4}$$

$$Ve = 1{,}23\ V/esp$$

Entonces se tiene que:

$$N_3 = \frac{Vs}{Ve}$$

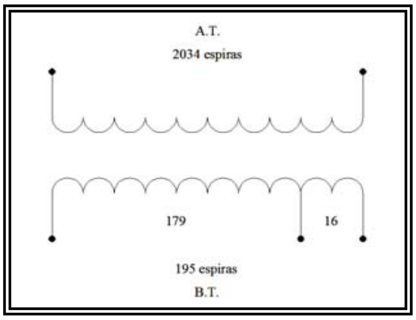
$$N_3 = \frac{2500\ V}{1{,}23\ V/esp}$$

$$N_3 = 2034{,}09\ esp$$

Redondeando tenemos que N_3=*2034 esp*.

Dado que el transformador a diseñar no cuenta con otras derivaciones o TAP's, no se necesitará realizar otros cálculos para número de espiras.

FIGURA 4-1
ESQUEMA DESARROLLADO DE LOS DEVANADOS (A.T., B.T.)



Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2011

4.4. Cálculo de los calibres del conductor

Para este cálculo es común tomar la densidad de corriente (δ), la cual debe estar dentro de los siguientes valores:

- Transformadores sumergidos en aceite: δ = 3,5 a 4,5 amperes/mm^2.
- Transformadores tipo seco: δ = 2,5 a 3,5 amperes/mm^2.

Para nuestro cálculo se toma una densidad de corriente de 3 amperes/mm^2, de allí se obtiene los calibres mediante la siguiente fórmula:

$$A_{Cu} = \frac{I}{\delta} \tag{4.5}$$

Para el lado de baja tensión se tomará la corriente Ip_1, la cual es la mayor de las dos secciones del devanado primario:

$$A_{Cu\,p} = \frac{Ip_1}{\delta}$$

$$A_{Cu\,p} = \frac{9{,}09\ A}{3\ A/mm^2}$$

$$A_{Cu\,p} = 3{,}03\ mm^2$$

De la tabla de calibres de conductores (anexo 3), se puede observar que 3,03 mm^2 corresponde a un calibre número 12 AWG, para la bobina de B.T.

Para el lado de alta tensión se tiene que:

$$A_{Cu\,s} = \frac{Is}{\delta}$$

$$A_{Cu\,s} = \frac{0{,}8\ A}{3\ A/mm^2}$$

$$A_{Cu\,s} = 0{,}27\ mm^2$$

De la tabla de calibres de conductores (anexo 3), se puede observar que 0,27 mm^2 corresponde a un calibre número 23 AWG, para la bobina de A.T.

4.5. Cálculo de la sección transversal del núcleo y sus dimensiones geométricas

Luego de haber calculado el número de espiras tanto en el lado de alta como el lado de baja y fijándose una densidad de flujo magnético (β) de 11000 gauss, entonces se puede calcular la sección trasversal del núcleo (A_n), aplicando la ecuación general del transformador.

$$A_n = \frac{V\ x\ 10^8}{4{,}44\ f\ N\ \beta}(cm^2) \tag{4.6}$$

Donde:

$V = 2500\ V$

$f = 60\ Hz$

$\beta = 11000\ gauss$

$N = número\ de\ espiras$

Reemplazando valores a la expresión se tiene que:

$$A_n = \frac{2500\ x\ 10^8}{4{,}44\ (60)\ (2034)\ (11000)}\ (cm^2)$$

$$A_n = 41{,}94\ cm^2$$

Si se usa acero eléctrico grado M – 4 en la construcción de núcleos arrollados, el factor de apilamiento (f_e), lo podemos considerar entre los valores de 0,95 a 0,97, en cambio para núcleos apilados el (f_e) está entre 0,93 a 0,95, para el cálculo que se está realizando se utilizará un (f_e) de 0,95, de allí tenemos que:

$$A_n = A_f \cdot f_e \qquad (4.7)$$

Donde:

A_n : Área neta

A_f : Área física

f_e : Factor de apilamiento, o de laminación, conocido también como factor de espacio.

Despejando A_f de la ecuación (4.7) se tiene que:

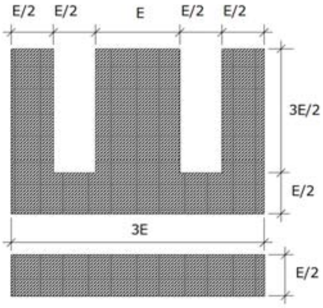
$$A_f = \frac{A_n}{f_e} \qquad (4.8)$$

$$A_f = \frac{41{,}94\ cm^2}{0{,}95}$$

$$A_f = 44{,}15\ cm^2$$

El circuito magnético de un transformador monofásico está caracterizado por dos áreas o superficies características: el Área de Núcleo, A_f, que es la superficie de la columna central del transformador, y el Área de Ventana, A_v, que es la superficie del hueco o ventana que queda entre la columna central y las laterales; en realidad es la superficie que estará ocupado por los bobinados de primario y secundario, así como por los aislamientos.

FIGURA 4-2
RELACIÓN DE ASPECTO DE CHAPAS MAGNÉTICAS



Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2011

Conociendo las dimensiones anteriores, se podrá escribir que las áreas definidas serán:

$$A_f = E \cdot D \qquad (4.9)$$

$$A_v = \frac{3E^2}{4} \qquad (4.10)$$

Siendo D la profundidad del núcleo. Habitualmente, siempre que sea posible, se suele tomar un valor de D parecido a E; así A_f será una superficie prácticamente cuadrada. Se puede tomar un valor de D distinto a E, pero es mejor que la superficie se acerque al cuadrado.

Despejando D de la ecuación (4.9) se tiene:

$$D = \frac{A_f}{E} \tag{4.11}$$

$$D = \frac{44,15\ cm^2}{6,4\ cm}$$

$$D = 6,9\ cm$$

Para determinar el número de chapas para formar un paquete o espesor (D), se lo determina considerando el espesor de la lámina, en este caso el espesor es de 0,5 mm que tiene el acero eléctrico grado M – 4, entonces se requiere:

$$N^\circ\ Chapas = \frac{D}{e} \tag{4.12}$$

Donde:

D : Profundidad del núcleo

e : Espesor de la chapa

Reemplazando valores se tiene que:

$$N^\circ\ Chapas = \frac{69\ mm}{0,5\ mm}$$

$$N^\circ\ Chapas = 138$$

Por lo general la altura de la ventana es 2,5 a 3,5 veces el ancho $(E/2)$, si se toma el valor de 3 se tiene qué:

$$h_v = 3\frac{E}{2} \tag{4.13}$$

$$h_v = 3 \cdot \frac{6{,}4\ cm}{2}$$

$$h_v = 9{,}6\ cm$$

4.6. Cálculo de las dimensiones generales de la bobina y del ancho de ventana de las arcadas del núcleo

Con lo calculado hasta el momento, se tienen los datos principales para poder dimensionar las bobinas del transformador y el ancho de ventana de las arcadas del núcleo.

4.6.1. Dimensionado de bobinas

4.6.1.1. Bobina de baja tensión (B.T.)

Para calcular la altura del devanado, se considera el nivel básico de impulso (BIL), así se tiene que para baja tensión corresponde una clase de aislamiento de 1,2 KV y un BIL de 30 KV, como se muestra en la tabla 4-2.

TABLA 4-2
DISTANCIAS MÍNIMAS PARA AISLAMIENTOS MAYORES

	Pruebas dieléctricas		Aislamiento entre bobinas de A.T.-B.T., aislamiento radial A.T.-núcleo							
Clase de aislamiento	**Nivel básico de impulso (BIL)**	**Potencial aplicado**	**Tubo de papel**	**Ducto de aceite**	**Envolvente**	**Total tolerancia**	**Collar**	**Aislamiento del yugo**	**Aislamiento entre fases**	**Claro bobina - tanque**
KV			**Milímetros**							
1,2	30	10	1,5	-	-	1,7	6,5	1,5	1,7	15
5	60	19	-	3	1	4,5	6,5	2,0	4,7	20
8,7	75	26	0,4	3	1	4,9	10	2,0	5,0	25
15	95	34	0,9	3	1	5,5	13	2,0	6,0	28
15	110	34	1,4	3	1	6,0	20	3,0	8,0	30
25	150	50	2,5	3	1,8	8,3	32	4,5	10	40
34,5	200	70	4,8	3	1,8	10,8	51	4,5	13	50

Fuente: PÉREZ Pedro Avelino, Transformadores de distribución, 2ª Edición, 2001
Elaborado por: Alvaro Aguirre / 2011

La altura efectiva del devanado (ver figura 4-3) será de:

$$he = h_v - 2(d_a + r_c) \tag{4.14}$$

Donde:

he = Altura efectiva del devanado

h_v = Altura de la ventana del núcleo

d_a = Distancia de aislamiento axial (formaleta)

r_c = Radio de curvatura del núcleo (0 mm)

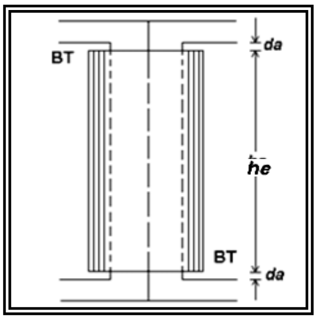
Reemplazando valores se tiene lo siguiente:

$$he_p = 9{,}6\ cm - 2(0{,}2\ cm + 0\ cm)$$

$$he_p = 9{,}6\ cm - 0{,}4\ cm$$

$$he_p = 9{,}2\ cm\ (92\ mm)$$

FIGURA 4-3
CORTE TRANSVERSAL DEL DEVANADO DE B.T.



Fuente: PÉREZ Pedro Avelino, Transformadores de distribución, 2ª Edición, 2001
Elaborado por: Alvaro Aguirre / 2011

Conocida la altura efectiva del devanado de B.T., se calcula el número de espiras por capa:

$$NC = \frac{he}{d_{cond}} \tag{4.15}$$

Donde:

NC : Espiras por capa

he : Altura efectiva del devanado

d_{cond} : Diámetro del conductor

Reemplazando valores se tiene:

$$NC_p = \frac{92\ mm}{2{,}14\ mm}$$

$$NC_p = 43$$

Para obtener el número de capas requerida se divide el número total de espiras entre las espiras por capa, de la siguiente manera:

$$C = \frac{N}{NC} \quad (4.16)$$

$$C_p = \frac{195}{43}$$

$$C_p = 4{,}53$$

Por facilidad y desde el punto de vista dieléctrico se ajusta el valor de espiras por capa a 40, entonces:

$$C_p = \frac{195}{40}$$

$$C_p = 4{,}88 \cong 5$$

En la última capa se devanan 35 espiras.

Seguidamente se calcula el espesor o dimensión radial de la bobina de B.T. mediante la ecuación:

$$d_{BT} = C \times d_{cond} \tag{4.17}$$

$$d_{BT} = 5 \times 2{,}14\ mm$$

$$d_{BT} = 10{,}7\ mm$$

A esta dimensión se da un 5% de tolerancia por concepto de uso de cintas y amarres, entonces resulta que:

$$d_{BT} = 10{,}7\ mm \times 1{,}05$$

$$d_{BT} = 11{,}24\ mm$$

La longitud de la vuelta media (L_{vmp}) del devanado primario, se calcula con la siguiente expresión:

$$L_{vmp} = 2(D + E) + \pi(2(d_{aisl}) + d_{BT}) \tag{4.18}$$

Donde:

D : Profundidad del núcleo

E : Ancho del núcleo

d_{aisl} : Espesor de formaleta

d_{BT} : Espesor del devanado de baja tensión

Dando valores a la expresión anterior se tiene que:

$$L_{vmp} = 2(6{,}9\ cm + 6{,}4\ cm) + \pi(2(0{,}2\ cm) + 1{,}124\ cm)$$

$$L_{vmp} = 26{,}6\ cm + 4{,}79\ cm$$

$$L_{vmp} = 31{,}39\ cm$$

La longitud del conductor requerido será:

$$L_{tBT} = N_2 \times L_{vmp} \tag{4.19}$$

$$L_{tBT} = 195 \times 31{,}39\ cm$$

$$L_{tBT} = 6121{,}05\ cm$$

$$L_{tBT} = 61{,}21\ m$$

A la longitud total del conductor del devanado de B.T. habrá que sumarle las distancias de las salidas de los bornes, un 1,5% no sería demasiado, entonces:

$$L_{TBT} = L_{tBT} \times 1{,}015$$

$$L_{TBT} = 61{,}21\ m \times 1{,}015$$

$$L_{TBT} = 62{,}13\ m$$

El peso del conductor (P_{BT}) por bobina será de:

$$P_{BT} = L_{TBT} \times P_{cond} \tag{4.20}$$

Donde:

L_{TBT} : Longitud total conductor en devanado B.T.

P_{cond} : Peso del conductor (ver anexo 3)

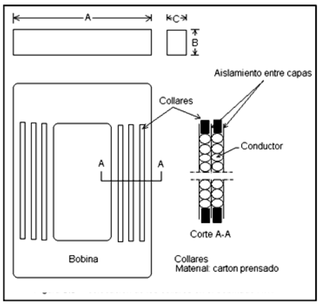
$$P_{BT} = 0{,}06213\ Km \times 29{,}78\ Kg/Km$$

$$P_{BT} = 1{,}85\ Kg$$

4.6.1.2. Dimensiones del bobinado de alto voltaje (A.T.)

El dimensionamiento de la bobina de alta tención no es tarea fácil, sin embargo no es complicado cuando se tiene una buena práctica en el diseño y se cuenta con la información suficiente como la información técnica de los fabricantes experimentados, sobre todo en cuanto al manejo de distancias dieléctricas se refiere y según los niveles a operar, en la tabla 4-2, se puede considerar algunos valores que generalmente le llaman "collares o collarines" (ver figura 4-4).

FIGURA 4-4
COLOCACIÓN DE LOS COLLARES EN EL DEVANADO A.T.



Fuente: PÉREZ Pedro Avelino, Transformadores de distribución, 2ª Edición, 2001
Elaborado por: Alvaro Aguirre / 2011

Según los cálculos realizados anteriormente, el conductor que utilizaremos para devanar la bobina de A.V. es el Nº 23 AWG, para la clase de aislamiento de 5KV, con el requerimiento que sea un conductor aislado con doble capa de esmalte. El conductor que hemos elegido es de productos magneto (ver anexo 3), con la información técnica de dicho conductor se procede a calcular la altura efectiva del devanado de A.T. mediante la fórmula 4.14.

$$he_s = h_v - 2(d_a + r_c)$$

$$he_s = 9{,}6\ cm - 2(0{,}65\ cm + 0\ cm)$$

$$he_s = 9{,}6\ cm - 1{,}3\ cm$$

$$he_s = 8{,}3\ cm\ (83\ mm)$$

Conocida la altura efectiva del devanado de A.T., se calcula el número de espiras por capa, utilizando la fórmula 4.15.

$$NC_s = \frac{he_s}{d_{cond}}$$

$$NC_s = \frac{83\ mm}{0{,}63\ mm}$$

$$NC_s = 132$$

Para obtener el número de capas requerida se reemplaza valores en la fórmula 4.16.

$$C_s = \frac{N_S}{NC_s}$$

$$C_s = \frac{2034}{132}$$

$$C_s = 15{,}41$$

Por facilidad y desde el punto de vista dieléctrico se ajusta el valor de espiras por capa a 130, entonces:

$$C_s = \frac{2034}{130}$$

$$C_s = 15{,}65 \cong 16$$

En la última capa se devanan 84 espiras.

Seguidamente se procede a calcular los aislamientos menores para la bobina de A.T.

En los transformadores el aislamiento entre espiras no constituye mayor complicación ya que el conductor tiene su aislamiento con una o varias capas de barniz, según se requiera, lo cual se puede verificar tanto a baja frecuencia como al impulso con la siguiente expresión:

$$Ed_e = \frac{Vpr}{N} \times Fs \tag{4.21}$$

Donde:

Ed_e : Esfuerzo dieléctrico entre vueltas

Vpr : Voltaje de prueba

N : Número de espiras

Fs : Factor de seguridad

Reemplazando valores tenemos que:

Para la prueba de voltaje inducido,

$$Ed_e = \frac{2500}{2034} \times 1{,}5$$

$$Ed_e = 1{,}84\ V$$

y para la prueba de impulso,

$$Ed_e = \frac{60000}{2034} \times 1{,}5$$

$$Ed_e = 44{,}25\ V$$

Para determinar el aislamiento entre capas se emplea la siguiente expresión:

$$Ed_c = \frac{2Vpr \times NC}{N} \times Fs \qquad (4.22)$$

Donde:

Ed_c : Esfuerzo dieléctrico entre capas

Vpr : Voltaje de prueba

NC : Espiras por capa

N : Número de espiras

Fs : Factor de seguridad

Reemplazando valores se tiene que:

Para la prueba de voltaje inducido,

$$Ed_c = \frac{2(2500) \times 130}{2034} \times 1{,}8$$

$$Ed_c = 575{,}22\ V$$

$$Ed_c = 0,58\ KV$$

y para la prueba de impulso,

$$Ed_c = \frac{2(60000) \times 130}{2034} \times 1,8$$

$$Ed_c = 13805,31\ V$$

$$Ed_c = 13,81\ KV$$

Los aislamientos a utilizarse puede seleccionarse mediante la tabla 4-3, las tensiones de ruptura del aislamiento elegido deberán exceder los valores calculados para Ed_c

TABLA 4-3
PROPIEDADES ELÉCTRICAS TÍPICAS NOMEX TIPO 410

Espesor nominal (mil) (mm)	2 0,05	3 0,08	5 0,13	7 0,18	10 0,25	12 0,30	15 0,38	20 0,51	24 0,61	25,5 0,65	29 0,73	30 0,76
Resistencia Dieléctrica - Subida Rápida CA[1]												
(V/mil)	430	550	680	840	815	820	830	810	800	730	750	680
(kV/mm)	17	22	27	33	32	32	33	32	31	29	30	27
- Impulso de Onda Completa[2]												
(V/mil)	1000	1000	1400	1400	1600	N/A	1400	1400	N/A	N/A	N/A	1250
(kV/mm)	39	39	55	55	63	N/A	55	55	N/A	N/A	N/A	49
Constante Dieléctrica[3] a 60 Hz	1.6	1.6	2.4	2.7	2.7	2.9	3.2	3.4	3.7	N/A	3.7	3.7
Factor de Disipación[3] a 60 Hz ($x10^{-3}$)	4	5	6	6	6	7	7	7	7	N/A	7	7

[1] ASTM D-149, electrodos de 50 mm, subida rápida; corresponde a IEC 243-1, subapartado 9.1 salvo por los electrodos de 50 mm. [2] ASTM D-3426 [3] ASTM D-150

Fuente: www.osdasrl.com.ar/pdf/tec410.pdf
Elaborado por: Alvaro Aguirre / 2011

El espesor total de la bobina lo determinamos en función de todos los materiales que intervienen en su construcción.

MATERIAL	Espesor radial (mm)	Total (mm)
Tubo de devanado (o casquillo)		
Formaleta	2,00	2,00
Bobina de baja tensión B.T.		
Conductor más aislamiento	11,24	11,24
Aislamiento B.T. – A.T.		
Diez capas de papel NOMEX de 0,18 mm	1,80	1,80
Bobina de alta tensión A.T.		
Diez y seis capas de conductor Nº 23 AWG	10,08	14,58
Aislamiento entre capas papel NOMEX de 0,25 mm	4,00	
Sobre aislamiento en la última capa	0,50	
	Total	**29,62**

La longitud de la vuelta media del devanado secundario se calcula de la forma siguiente:

$$L_{vms} = 2(D + E) + \pi\left(2\left(d_{casq} + d_{BT} + d_{aislAT-BT}\right) + d_{AT}\right)$$

Dando valores se tiene que:

$$L_{vms} = 2(6{,}9\ cm + 6{,}4\ cm) + \pi(2(0{,}2\ cm + 1{,}124\ cm + 0{,}18\ cm) + 1{,}458\ cm)$$

$$L_{vms} = 26{,}6\ cm + 14{,}03\ cm$$

$$L_{vms} = 40{,}63\ cm$$

La longitud total del conductor requerido será:

$$L_{tAT} = N_3 \times L_{vms}$$

$$L_{tAT} = 2034 \times 40{,}63\ cm$$

$$L_{tAT} = 82641{,}42\ cm$$

$$L_{tAT} = 826{,}41\ m$$

El peso del conductor por bobina debe ser de:

$$P_{AT} = L_{tAT} \times P_{cond}$$

Donde:

L_{tAT} : Longitud total conductor en devanado A.T.

P_{cond} : Peso del conductor (ver anexo 3)

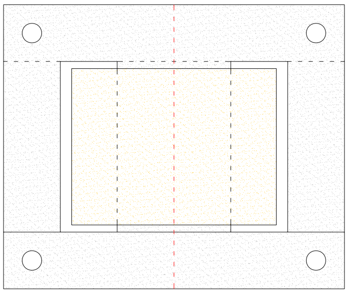
$$P_{AT} = 0{,}82641\ Km \times 2{,}375\ Kg/Km$$

$$P_{AT} = 1{,}96\ Kg$$

4.6.2. Determinación del ancho de ventana del núcleo y el peso por arcada

De la figura 4-2, para efectos de cálculo, se puede decir que el núcleo se encuentra dividido en dos arcadas idénticas, pudiéndolo observar claramente en el esquema núcleo-bobina de la figura 4-5.

FIGURA 4-5
DIAGRAMA DE CORTE DEL CONJUNTO NÚCLEO-BOBINA



Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2011

De la figura anterior, se observa que en ambas arcadas se aloja un espesor de bobina igual, luego entonces, se determina el ancho (A) de ventana correspondiente a ambas arcadas, figura 4-6.

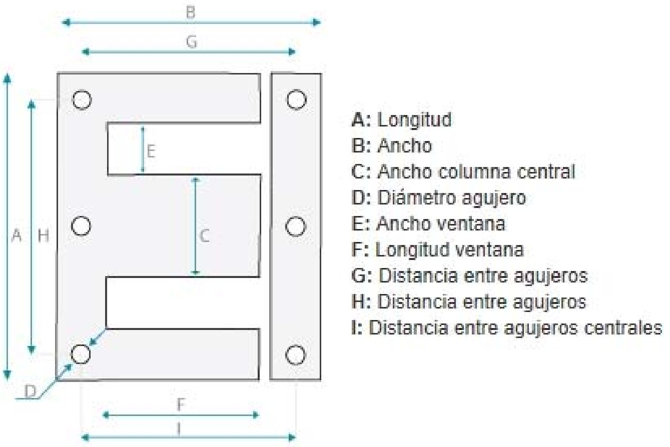
Tomando en cuenta las medidas de la columna del núcleo de hierro y el espesor total de la bobina calculados anteriormente, se procede a seleccionar de las laminaciones prefabricadas disponibles en el mercado, la que se ajuste a las necesidades, y del caso de no contar con una laminación apropiada, se procederá a la fabricación de las mismas con las medidas requeridas.

Sabiendo que el espesor total de la bobina es de 29,62 mm se buscará una laminación que cuente con un ancho de ventana de por lo menos 30 mm y que se ajuste a las demás medidas calculadas.

En este caso si se cuenta con una laminación tipo EI prefabricada que se ajusta al requerimiento, la cual se selecciona de la siguiente tabla.

TABLA 4-4
MEDIDAS DE LAMINACIONES PREFABRICADAS

Serie E&I Monofásico



TIPO	A	B	C	D	E	F	G	H	I	KG.CM
EI.	40	34	13		7	20	=	=	27	0,084
EI.	48	40	16	3,5	8	24	=	=	34,5	0,116
EI.	54	45	18	3,5	9	27	36	45	=	0,149
EI.	57	47,5	19	3,5	9,5	28,5	=	=	42	0,166
EI.	60	50	20	3,5/4	10	30	40	50	45	0,184
EI.	66	55	22	4,5	11	33	44	55	47,5	0,221
EI.	75	62,5	25	4,5/5,5	12,5	37,5	50	62,5	55	0,287
EI.	84	70	28	4,5/6	14	42	56	70	62,5	0,362
EI.	96	80	32	5,5	16	48	64	80	68	0,472
EI.	108	90	36	5,5	18	54	72	90	79	0,599
EI.	114,2	95,1	38	5,5	19,1	57,1	75,4	94,3	=	0,669
EI.	135	112,5	45	7,5	22,5	67,5	90	112,5	99	0,934
EI.	150	125	50	8	25	75	100	125	110	1,154
EI.	180	150	60	9,0/10	30	90	120	150	134	1,665
EI.	192	160	64	11	32	96	128	160	144	1,887
EI.	220	190	70	12	40	110	150	180	=	2,538
EI.	240	200	80	11,5	40	120	160	200	=	2,947
EI.	300	250	100	12,5	50	150	190	250	=	4,641

Fuente: www.franainternational.com
Elaborado por: Alvaro Aguirre / 2011

Las medidas de laminación que se seleccionaron son:

A: 192 mm

B: 160 mm

C: 64 mm

D: 11 mm

E: 32 mm

F: 96 mm

G: 128 mm

H: 160 mm

I: 144 mm

Habiendo seleccionado las medidas de laminación para el núcleo del transformador se calcula el peso total del núcleo, tomando el dato del fabricante acerca del peso por profundidad de apilamiento, entonces:

$$P_t = (6{,}9)(1{,}887)$$

$$P_t = 13{,}02\ Kg$$

CAPÍTULO V

CONSTRUCCIÓN

5.1. Clasificación de las partes de la fuente de poder

La fuente de poder consta de varias partes las cuales están divididas en dos grupos un principal y un auxiliar como se puede observar a continuación:

5.1.1. Partes principales

- Transformador elevador
- Transformador variable

5.1.2. Partes auxiliares

- Carcasa o gabinete
- Conductores
- Medio refrigerante
- Interruptores
- Indicadores

5.2. Descripción breve de la construcción de los transformadores

5.2.1. Núcleos

"El circuito magnético es la parte componente del transformador que servirá para conducir el flujo magnético generado, el cual concatenará magnéticamente los circuitos eléctricos del transformador. El circuito magnético se conoce comúnmente como núcleo. Este núcleo se encuentra formado por láminas de acero al silicio de grano orientado de bajas pérdidas y una alta permeabilidad magnética.

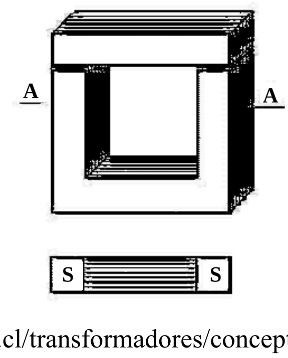
Todas las láminas están aisladas en ambas caras por medio de un aislante inorgánico llamado ***"carlite"*** que consiste de una capa especial aplicada en el proceso final de planchado y reconocido."[4]

De acuerdo con la posición que existe entre la colocación de las bobinas y el núcleo, se conocen dos tipos fundamentales, ellos son el tipo columna y el tipo acorazado, los cuales se detallan a continuación.

5.2.1.1. Núcleo tipo columna

Es aquel en el cual las bobinas abarcan una parte considerable del circuito magnético, este tipo de núcleo se representa en la Figura 5.1, indicando el corte A-A la sección transversal que se designa con S (cm^2). Este núcleo no es macizo, sino que está formado por un paquete de chapas superpuestas, y aisladas eléctricamente entre sí. Para colocarlas y poder ubicar el bobinado terminado alrededor del núcleo, se construyen cortadas, colocando alternadamente una sección U con una sección I. La capa siguiente superior cambia la posición I con respecto a la U.

FIGURA 5-1
VISTA Y CORTE DE UN NÚCLEO TIPO COLUMNA.



Fuente: patricioconcha.ubb.cl/transformadores/conceptos_practicos_de_diseno.htm
Elaborado por: Alvaro Aguirre / 2012

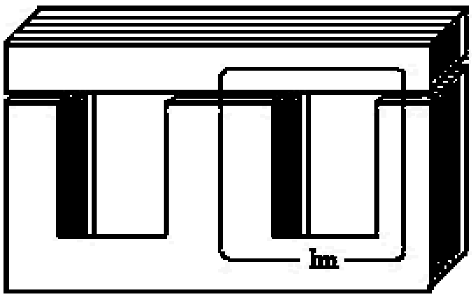
[4] PÉREZ Pedro Avelino, Transformadores de distribución, Segunda Edición, 2001, Pág. 10.

El aislamiento entre chapas se consigue con barnices especiales, con papel de seda, o simplemente oxidando las chapas con un chorro de vapor.

5.2.1.2. Núcleo tipo acorazado

Es aquel en el cual el núcleo se encuentra cubriendo los devanados de baja y alta tensión, este tipo de núcleo es el más utilizado, pues se reduce la dispersión del campo magnético, se representa en la Figura 5.2, en vistas. Obsérvese que las líneas de fuerza de la parte central, alrededor de la cual se colocan las bobinas se bifurcan abajo y arriba hacia los dos costados, de manera que todo el contorno exterior del núcleo puede tener la mitad de la parte central. Esto vale para las dos ramas laterales como también para las dos cabezas. Para armar el núcleo acorazado también se lo construye en trozos, unos en forma de E y otros en forma de I, y se colocan alternados, para evitar que las juntas coincidan.

FIGURA 5-2
VISTA DE UN NÚCLEO TIPO ACORAZADO CON INDICACIÓN DE LA LONGITUD MAGNÉTICA MEDIA.



Fuente: patricioconcha.ubb.cl/transformadores/conceptos_practicos_de_diseno.htm
Elaborado por: Alvaro Aguirre / 2012

El hecho que los núcleos sean hechos en dos trozos, hace que aparezcan juntas donde los filos del hierro no coinciden perfectamente, quedando una pequeña luz que llamaremos entrehierro. Obsérvese que en el tipo columna hay dos entrehierros en el recorrido de las fuerzas, y que en el tipo acorazado también, porque los dos laterales son atravesados por la mitad de líneas cada uno.

5.2.2. Devanados

“Los devanados son la parte que componen los circuitos eléctricos del transformador (devanados primarios y secundarios). Los devanados se fabrican en diferentes tipos dependiendo de las necesidades del diseño, y los materiales que se utilizan, básicamente, son: el cobre y el aluminio.

La función de los devanados (primarios) es crear un flujo magnético para inducir en los devanados (secundarios) una fuerza electromotriz, y transferir potencia eléctrica del primario al secundario mediante el principio de inducción electromagnética; este proceso se desarrolla con una pérdida de energía muy pequeña.”[5]

Hay dos formas típicas de devanados para transformadores, los cilíndricos y los planos. Los núcleos, con su forma, son los que determinan la elección de uno u otro tipo, salvo que se requieran propiedades especiales, como ser baja capacidad distribuida, para uso en telecomunicaciones u otros.

- **Bobinado cilíndrico:** Este tipo se usa cuando el núcleo del transformador es del tipo apilado y escalonado.
- **Bobinado plano:** Este tipo se usa cuando el núcleo del transformador es del tipo acorazado.

Los dos bobinados primario y secundario, rara vez se apartan en dos simples grupos de espiras, encimándolas; generalmente se apartan en dos partes o más envueltas uno encima del otro, con el devanado de bajo voltaje en la parte interna. Dicha conformación sirve para los siguientes propósitos.

- Simplifica el problema de aislar el devanado de alto voltaje del núcleo.

[5] PÉREZ Pedro Avelino, Transformadores de distribución, Segunda Edición, 2001, Pág. 11.

- Causa mucho menos filtración de flujo, como sería el caso si los 2 devanados estuvieran separados por alguna distancia del núcleo.
- Mejora la refrigeración.

Los materiales aislantes para el bobinado, o para colocar entre capas, son: papel prespan, papel nomex, fibra de vidrio, micanita, cinta impregnada, algodón impregnado, etc., para transformadores con bobinados al aire, y para los sumergidos en baños de aceite, se utilizan los mismos materiales sin impregnarse; debe evitarse el uso del caucho en los transformadores en baño de aceite, pues este lo ataca, y tiene efectos nocivos también sobre la micanita y aun sobre los barnices.

Las piezas separadoras entre bobinados, secciones, o entre estas y el núcleo pueden ser de madera, previamente cocida en aceite, aunque actualmente se prefieren los materiales duros a base de papel o similares (pertinaz, etc.). Si se usa madera, no debe interpretarse como que se dispone de aislamiento, sino solamente de un separador.

En cuanto a los conductores para hacer bobinas, su tipo depende de la sección, pues hasta $6mm^2$ pueden usarse alambre y más arriba de ese límite se usan cables de muchos hilos, o bien cintas planas, para facilitar el bobinage. El aislamiento para los conductores puede ser algodón, que luego se impregnará si no se emplea baño de aceite. Para transformadores de soldadura que trabajan con voltajes muy bajos y corrientes muy fuertes, se suelen colocar las cintas de cobre sin aislamiento, pues la resistencia de contacto entre ellas es suficiente para evitar drenajes de corriente. Esta situación mejora aún debido a la oxidación superficial del cobre.

5.3. Construcción del transformador elevador

5.3.1. Construcción de las bobinas

En esta sección se construye la parte activa del transformador, el proceso de construcción de las bobinas es el mismo tanto para transformadores como para auto transformadores, sean estos secos o en aceite, a continuación el detalle del proceso.

Proceso de confección de las bobinas

1. Cálculo de la bobina.
2. Diagrama de la bobina.
3. Selección de la formaleta.
4. Montaje de la formaleta en la máquina bobinadora.
5. Montaje de aislamientos BT (baja tensión) contra formaleta.
6. Confección del arrollamiento de BT.
7. Montaje de aislamiento AT (alta tensión) contra BT.
8. Confección del arrollamiento de AT.
9. Retirar la formaleta con el bobinado de la máquina.
10. Bobina lista para montar en el núcleo.

Todo empieza con los cálculos previos para las bobinas de baja y media tensión, teniendo en cuenta los aspectos básicos como son potencia, voltaje del primario, voltaje del secundario, frecuencia, etc.

Con los cálculos listos se procede a diseñar el tipo de bobina y la formaleta que se va a usar, la formaleta se la construye en el caso de no existir alguna elaborada que coincida con las medidas requeridas, una vez que se tiene la formaleta se procede a colocarla en la máquina bobinadora, asegurándose de que a más de estar centrada este muy bien fijada ya que a medida que se va elaborando la bobina esta adquiere volumen y peso que son de gran consideración.

El bobinado tiene su principio el mismo que sale a un extremo de la bobina, como se puede apreciar en la figura 5-3, se empieza a envolver el conductor aislado ya sea con esmalte (de fábrica conductor esmaltado) o con papel presspan esto debido a que los conductores van ligados entre espiras y pueden entrar en cortocircuito, de acuerdo con el diseño algunas bobinas tienen varias derivaciones, estas de igual forma salen a un mismo lado de la bobina.

FIGURA 5-3
CONSTRUCCIÓN DE LAS BOBINAS DE B.T. Y A.T.

Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2012

Como una bobina está constituida de varias espiras y varias capas el paso de una capa a otra no se bobina hasta los extremos ya que se debe poner un aislamiento con suficiente distancia que soporte las tensiones mecánicas.

Entre capas de cobre arrollado en la bobina se aísla con papel nomex, este aislamiento tiene el suficiente espesor para soportar el voltaje de ruptura entre capas según las normas.

Una vez elaborada la bobina se procede a retirar de la máquina bobinadora, para luego montar la bobina en el núcleo.

5.3.2. Armado del núcleo

En esta sección ingresan láminas de acero al silicio pre cortado de acuerdo con el diseño para en lo posterior armar el núcleo, a continuación los pasos que se siguen para el dimensionamiento y armado del núcleo:

Proceso de dimensionamiento y armado del núcleo.

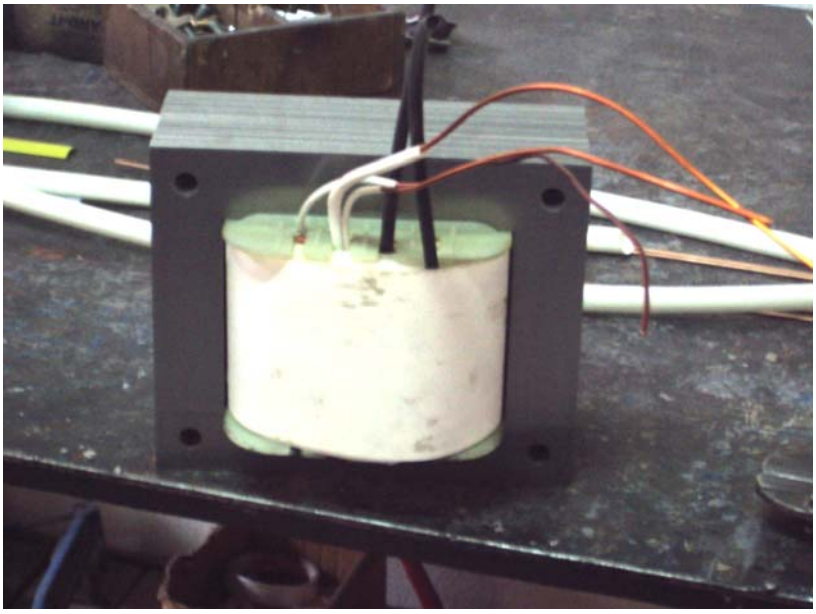
1. Cálculo del núcleo
2. Selección de laminaciones
3. Ensamble del núcleo
4. Verificación de las medidas totales del núcleo
5. Prensado del núcleo
6. Núcleo terminado

Este proceso al igual que el proceso anterior, comienza con los cálculos previos para el núcleo, teniendo en cuenta que contamos con una gama de laminaciones pre cortadas, de las cuales debemos seleccionar una de ellas según las medidas calculadas para nuestro núcleo.

Ya con las piezas seleccionadas procedemos a armar el núcleo, esto se lo hace directamente en la bobina, introduciendo la columna central de la lámina tipo E dentro de la formaleta de la bobina, es necesario que al poner lámina con lámina quede sin aberturas, y de acuerdo al modelo intercalar las mismas de tal manera que forme un núcleo más firme y permita un mejor flujo magnético.

Cuando se tiene el núcleo armado se comprueba si esta en las medidas adecuadas y de acuerdo a los cálculos.

FIGURA 5-4
NÚCLEO ARMADO Y LISTO PARA EL PRENSADO



Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2012

Una vez terminado el armado del núcleo se procede a prensarlo para evitar que se desarme y para que sea fácil su transportación, esto se lo consigue con la colocación de cuatro pernos, uno en cada esquina del núcleo, y utilizando cuatro platinas colocadas a ambos lados del núcleo, tanto en la parte frontal como en la posterior.

5.3.3. Conexionado

En este proceso se realiza todas las conexiones que permiten el funcionamiento del transformador, aquí las bobinas y el núcleo se denominan como la parte activa del transformador. De acuerdo al propósito del transformador y los requerimientos del proyecto se realiza los siguientes pasos:

1. Identificación de las puntas salientes de cada bobina
2. Instalación de la bornera
3. Aislamiento de conexiones
4. Conectar la baja tensión

5. Conectar la alta tensión
6. Pruebas al transformador

Se identifica bobinado de baja tensión y alta tensión, cortamos las puntas de estos de acuerdo a la distancia hacia la bornera donde en lo posterior irán fijados a los respectivos elementos de acople.

Colocamos una bornera fabricada en fibra, fijándola al transformador por medio de los dos pernos superiores utilizados para el prensado de las láminas del núcleo.

Antes de realizar las conexiones se aíslan todos los conductores de tal forma que se pueda evitar el contacto de los mismos, el aislamiento se lo hace con papel crepe pegándolo con reometol y luego forrándole con tubo de fibra, tal como se muestra en la figura 5-5.

FIGURA 5-5
AISLADO DE CONEXIONES

Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2012

Luego de aislados los conductores se procede a su conexión en la bornera, tomando en cuenta las separaciones mínimas que estas deben tener en función del nivel de voltaje a conducir.

Primeramente se realizan las conexiones de alta tensión ya que cuenta únicamente con dos conductores, los cuales podemos disponer en la bornera de cualquier forma.

Seguidamente se procede a realizar el conexionado de baja tensión, identificando previamente los dos circuitos y el conductor común entre ambos, obteniendo así una clara identificación de las conexiones en baja tensión.

Una vez terminadas las conexiones, tanto de alta como de baja tensión, procedemos a realizar las pruebas necesarias al transformador terminado en su totalidad.

5.4. Construcción del gabinete

El gabinete, al igual que la bobina y el núcleo, debe cumplir con un procedimiento para su construcción, el cual se detalla a continuación:

Proceso de construcción del gabinete

1. Diseño del gabinete
2. Corte de láminas para la elaboración del gabinete
3. Doblez de láminas
4. Ensamblado, remachado y soldado de laminas a conformar el gabinete
5. Perforación de las láminas para dispositivos y accesorios
6. Pintura del gabinete
7. Gabinete terminado

En este proceso se diseña y calcula las dimensiones del gabinete teniendo las medidas del tamaño que tiene la parte activa, y de acuerdo a la potencia del transformador se diseña el sistema de enfriamiento del mismo.

Se compran las láminas del espesor indicado para resistir el esfuerzo mecánico, se realizan los cortes necesarios y se envía a doblar ya que no se cuenta con máquinas adecuadas para el trabajo requerido.

Una vez con las láminas cortadas y dobladas a medida se procede a ensamblar y soldar el cuerpo del tanque con suelda eléctrica y oxiacetilénica, tomando en cuenta que el mismo está sujeto a grandes esfuerzos mecánicos, en las figuras 5.6 y 5.7, se puede apreciar el gabinete en proceso de fabricación.

FIGURA 5-6
CONSTRUCCIÓN DEL GABINETE

Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2012

FIGURA 5-7
GABINETE CON PERFORACIONES PARA VENTILACIÓN Y ACCESORIOS

Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2012

Culminado el proceso de ensamblado del gabinete se realiza las perforaciones necesarias para la instalación de los dispositivos y accesorios para nuestra fuente de poder.

Seguidamente, habiendo terminado todos los trabajos mecánicos en el gabinete, y no faltando nada más por realizar, procedemos a la pintura y acabados del mismo, requiriendo para esto de personal idóneo y experimentado en el campo de la pintura, para de esta manera brindar unos acabados de calidad.

En la siguiente figura podemos apreciar el gabinete terminado en su totalidad, listo para el montaje de los equipos, dispositivos y accesorios.

FIGURA 5-8
GABINETE TERMINADO

Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2012

5.5. Montaje de equipos, dispositivos y accesorios

Una vez concluida la construcción del gabinete procedemos a realizar el montaje de los equipos, dispositivos y accesorios, con su respectivo cableado, de la siguiente manera:

1. Instalación de accesorios en la parte posterior del gabinete
2. Montaje del transformador
3. Montaje del variac
4. Instalación de dispositivos de control y medición
5. Realización del cableado

Primeramente se instalan los accesorios que van colocados en la parte posterior del gabinete, como son los prensa estopa, necesarios para la salida y anclaje de los conductores principales del equipo.

FIGURA 5-9
INSTALACIÓN DE ACCESORIOS

Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2012

Luego de esto se continúa con el montaje del transformador, el cual se realiza instalando cuatro pernos en la base del mismo, anclándolo fuertemente a la base del gabinete.

FIGURA 5-10
MONTAJE DEL TRANSFORMADOR

Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2012

Para el montaje del variac es necesario desarmar la carcasa del mismo, para sujetarlo mediante dos asas existentes a la parte superior del gabinete, luego de esto se rearma y se coloca una base sujeta al gabinete, en la cual descansará el variac.

FIGURA 5-11
MONTAJE DEL VARIAC

Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2012

Habiendo montado los dos equipos en el gabinete se instala los dispositivos de medición y control en la puerta del mismo, estos nos ayudarán en el control de encendido, apagado y para las mediciones eléctricas necesarias.

FIGURA 5-12
INSTALACIÓN DE DISPOSITIVOS DE MEDICIÓN Y CONTROL

Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2012

Teniendo ya instalados todos los componentes de la fuente de poder, se realiza el cableado de los equipos y dispositivos para su funcionamiento, realizando pruebas para su verificación.

FIGURA 5-13
CABLEADO INTERNO DE LA FUENTE DE PODER

Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2012

CAPÍTULO VI

ANALISIS ECONOMICO

6.1. Costos de la parte eléctrica

A continuación se detalla los costos de los materiales eléctricos utilizados en la construcción de la fuente de poder.

TABLA 6-1
COSTOS PARTE ELÉCTRICA

CANT	DESCRIPCIÓN	VALOR UNITARIO	VALOR TOTAL
1	Transformador 1Φ seco 2kVA TP:220V TS:2500V	336,00	336,00
1	Transformador variable 2kVA TP:220V TS:0-250V	265,00	265,00
2	Voltímetro 72x72mm 300V	11,06	22,12
1	Selector 2 posiciones 2 contactos NA	18,60	18,60
5	Cable flexible 14 AWG mts	0,32	1,60
3	Cable concéntrico 3x14 AWG mts	1,92	5,76
7	Cable para bujía 18 AWG mts	0,83	5,81
14	Terminal U 3/16 16-14 azul	0,05	0,70
2	Lagarto pequeño c/forro rojo/negro	0,20	0,40
		TOTAL	**655,99**

Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2012

6.2. Costos de la parte mecánica

En el siguiente cuadro se detalla los costos de los materiales mecánicos necesarios para la construcción del presente equipo.

TABLA 6-2
COSTOS PARTE MECÁNICA

CANT	DESCRIPCIÓN	VALOR UNITARIO	VALOR TOTAL
1	Tool galvanizado 1/20 plancha	32,91	32,91
1	Kilo suelda AGA E 6011	3,85	3,85
1	Bisagra piano	7,29	7,29
2	Garrucha industrial 10 cm	2,69	5,38
1	Varilla 1/2 x 0,5 m	2,32	2,32
1	Tubo galvanizado 3/4 x 0,4 m	2,00	2,00
50	Remache 3/16	0,05	2,50
1	Broca titanio 3/16	2,50	2,50
1	Cerradura CSC c/llave	8,74	8,74
1	Fondo y pintura	50,00	50,00
		TOTAL	**117,49**

Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2012

6.3. Costos de transporte y envío

En la siguiente tabla se detallan los costos de transporte y envío en que se incurrió para la realización del presente trabajo de tesis.

TABLA 6-3
COSTOS DE TRANSPORTE Y ENVÍO

CANT	DESCRIPCIÓN	VALOR UNITARIO	VALOR TOTAL
1	Viajes	103,20	103,20
1	Transportación local	50,00	50,00
1	Envío de paquete internacional	85,55	85,55
		TOTAL	**238,75**

Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2012

6.4. Costos de mano de obra

A continuación se detallan los costos de la mano de obra.

TABLA 6-4
COSTOS MANO DE OBRA

CANT	DESCRIPCIÓN	VALOR UNITARIO	VALOR TOTAL
1	Construcción mecánica	50,00	50,00
1	Servicio de pintura	20,00	20,00
1	Dobleces	20,00	20,00
		TOTAL	**90,00**

Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2012

6.5. Costos totales

Aquí detallamos los costos totales del proyecto donde se incluye la parte eléctrica, la parte mecánica, la mano de obra, el transporte y envío que se requirió para la construcción de la fuente de poder.

TABLA 6-5
COSTOS TOTALES

DESCRIPCIÓN	VALOR
Parte eléctrica	655,99
Parte mecánica	117,49
Transporte y envío	238,75
Mano de obra	90,00
TOTAL	**1102,23**

Fuente: Investigación de campo
Elaborado por: Alvaro Aguirre / 2012

CAPÍTULO VII

CONCLUSIONES Y RECOMENDACIONES

7.1. Conclusiones

- ✓ Se ha construido una fuente de poder capaz de manejar valores de voltaje en la salida desde 0 hasta 2500 voltios.

- ✓ Al momento de la investigación para la realización del presente trabajo de tesis no se encontró bibliografía especializada en la biblioteca universitaria del campus.

- ✓ Puesto que en el país no se cuenta con un centro de certificación para máquinas soldadoras, el equipo fabricado servirá para la puesta en marcha de uno de estos centros.

- ✓ En nuestra localidad no se cuenta con empresas especializadas prestas a brindar asesoramiento fuera de su línea de producción.

- ✓ Las pruebas de alto potencial sirven para garantizar que el sistema de aislamiento funciona correctamente y que no se va a producir ningún arco entre los diferentes componentes eléctricos y la carcasa.

- ✓ La fuente de poder construida presenta todas las condiciones funcionales y estéticas que demanda cualquier trabajo de titulación.

7.2. Recomendaciones

- ✓ Se recomienda instruir al personal responsable del manejo de la fuente de poder, para de esta manera evitar riesgos laborales y posibles accidentes.

- ✓ Se recomienda la adquisición de bibliografía especializada para la carrera de electromecánica.

- ✓ Tener especial cuidado con las salidas de alto voltaje puesto que se podría producir un arco eléctrico y causar daños tanto a equipos como al personal.

- ✓ Antes de iniciar cada prueba se debe realizar mediciones de voltaje para asegurar el correcto funcionamiento del equipo.

- ✓ Se deberá dar mantenimiento preventivo a la fuente de poder, guardando especial cuidado al revestimiento de los cables de alta tensión y a la jaula de faraday, puesto que el correcto estado físico de estos garantizarán la seguridad del personal y los equipos.

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ANEXOS

ANEXO 1

NORMAS NEMA EW-1 Y EW-3

NEMA STANDARDS PUBLICATION NO. EW 1

nema

Electric Arc Welding Power Sources

NEMA

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 20037

NOTICE AND DISCLAIMER

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26 October 1989
NEMA EW 1-1988
1988
SUPERSEDING
NEMA EW 1-1983 (R1988)
1983

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TABLE OF CONTENTS

		Page
	FOREWORD	i
	PURPOSE	ii
	SCOPE	iii
Section 1	REFERENCED STANDARDS	
	Referenced Standards	1
	Definitions	2
Section 2	GENERAL	
	Suitability of Operation	6
	Arc Welding Power Source with Integral Wire Feed Unit	6
	Service Conditions	6
	Usual Service Conditions	6
	Unusual Service Conditions	6
	Installation and Operation	6
Section 3	CONSTRUCTION REQUIREMENTS—MECHANICAL CONSIDERATIONS	
	Frame and Enclosure	7
	Enclosure Construction	7
	Openings in Enclosures	8
	Corrosion Protection	8
	Service Line Hoses	8
	Water Cooling	9
	Brushes	9
	Jerk and Drop Tests	9
	Stacking of Arc Welding Power Sources	9
Section 4	CONSTRUCTION REQUIREMENTS—ELECTRICAL CONSIDERATIONS	
	Power Supply Connection-General	13
	Power Supply By Flexible Cord	13
	Power Supply By Permanent Wiring System	14
	Grounding	14
	Corrosion Protection	14
	Output Provisions	15
	Internal Wiring Requirements	16
	Spacings	16
	Classification of Insulation Systems	16
	Requirements For Specific Components	16
	Output Regulating Taps	17
	Auxiliary Power Supply	17
	Short Circuit of Welding Circuit	17
Section 5	RATINGS AND PERFORMANCE	
	Input Ratings of Arc Welding Power Sources Operating From Electrical Power Supplies	19
	Power Factor Correction	19
	Open Circuit Voltage	19

Output Ratings of Constant Current NEMA Class I Arc Welding Power Sources 19
Output Ratings of Constant Current NEMA Class II Arc Welding Power Sources 21
Output Ratings of Constant Current NEMA Class III Arc Welding Power Sources 21
Output Ratings of Constant Voltage NEMA Class I Arc Welding Power Sources 23
No Load Operation 23
Temperature Rise 23
Nameplate Marking 24

Section 6 TEMPERATURE TESTS
Testing Procedures for Arc Welding Power Sources 26
Thermometer Method of Temperature Determination 26
Resistance Method of Temperature Determination 26
Applied Thermocouple Method of Temperature Determination 26
Determination of Ambient Temperature 27
Cooling Air Temperature During Tests 27
Omission of Temperature Test on Duplicate Apparatus 27
Correction of Temperature to Time of Shutdown 27
Stopping Generator-Type Power Sources for Temperature Tests 27

Section 7 HIGH-POTENTIAL TESTS
High-Potential Tests 28
Test Voltage 28
Duration of Application of Test Voltage 28
Points of Application of Test Voltage 28
Temperature at Which High Potential Tests Are To Be Made 28
High Potential Test Procedure for Components and Accessories 28
Production Line High Potential Testing 28

Section 8 EFFICIENCY AND POWER FACTOR
Method of Determining Efficiency and Power Factor 30

Section 9 POWER SOURCES TO BE USED WITH GAS TUNGSTEN ARC WELDING (GTAW)
General 31
Definitions 31
Volt Ampere Relationship for GTAW 31
Categories of GTAW Power Sources 31
Nameplate Marking 32

Section 10 ARC WELDING POWER SOURCES WITH HIGH FREQUENCY ARC STARTING AND/OR STABILIZING
General 33
Definitions 33
HF Classification 33
Radio Frequency Radiation 33
General Principles for Installation of High Frequency Stabilized Arc Welding Installations 34
Certifications of HFSAW Installations 35

LIST OF TABLES

Table 3-1 Minimum Thickness of Sheet Metal for Enclosures – Carbon Steel or Stainless Steel . . 10

Table 3-2 Minimum Thickness of Sheet Metal for Enclosures – Aluminum, Copper, or Brass . . . 11

Table 3-3 Minimum Thickness of Cast Metal for Enclosures 12

Table 4-1 Conductor Size of Cords 13

Table 4-2 Size of Insulated Copper Conductors 13

Table 4-3 External Pulling Forces 14

Table 4-4 Diameter or Knockout of Hole for Conduit and Width of Surrounding Flat Surface . . . 14

Table 4-5 Spacings in Arc Welding Power Sources 15

Table 5-1 Constant Current, AC or DC NEMA Class I Arc Welding Power Sources 20

Table 5-2 Constant Current, AC/DC NEMA Class I Arc Welding Power Sources 20

Table 5-3 Constant Current, AC or DC NEMA Class II Arc Welding Power Sources 21

Table 5-4 Constant Current, AC/DC NEMA Class II Arc Welding Power Sources 22

Table 5-5 Constant Current, NEMA CLASS III Arc Welding Power Sources 22

Table 5-6 Constant Voltage, AC or DC NEMA Class I Arc Welding Power Sources 23

Table 5-7 Maximum Temperature Rise for DC Generator, AC Generator-rectifier and AC Generator Arc Welding Power Sources 24

Table 5-8 Maximum Temperature Rise for AC Transformer, DC Transformer – Rectifier and AC or DC Transformer-Rectifier Arc Welding Power Sources 25

LIST OF FIGURES

Figure 3-1 Probe 8

Figure 3-2 Enclosure Opening 8

Figure 10-1 Test Setup 37

Foreword

The standards in this publication represent the technical judgement of the Arc Welding Section with respect to the performance and construction of electric arc welding power sources. These standards are based upon sound engineering principles, research, records of tests, and field experience. The standards cover both installation and manufacturing criteria obtained from manufacturers and users.

To obtain input, copies of the proposed standard were sent to a number of individuals and organizations in the public and private sectors having an interest in or responsibility for the purchase, testing, application, use, or inspection of this product category. Comments and suggestions received during the draft stage resulted in a number of substantive changes being made in this publication.

As future major revisions to this publication are proposed, appropriate individuals and organizations will be canvassed.

Publication No. EW 1-1988 revises and reaffirms the content of NEMA Standards Publication for Electric Arc Welding Power Sources Publication No. EW 1-1983. The unchanged NEMA Standards and Authorized Engineering Information appear in this publication with the original EW 1-1983 date. Those that have been revised are followed by their appropriate classification and the date.

The values stated in U.S. customary (inch) units are to be regarded as the standard. Calculated SI (millimeter) equivalents of the U.S. customary (inch) units have been included. The SI units of measurement are those adopted by the General Conference on Weights and Measures (CGPM) as the International System of Units (Systeme Internationale D'Unites) and are sometimes referred to as the "modern metric system."

Proposed or recommended revisions to this Standards Publication should be submitted to:

Manager, Engineering Department
National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, DC 20037

Purpose

This NEMA Standards Publication is adopted in the public interest and is designed to eliminate misunderstandings between the manufacturer and purchasers and to assist purchasers in selecting and obtaining the proper product for their particular need.

Recommended safe practices intended to prevent personal injury and property damage arising out of the installation and use of this equipment are covered more completely in other related safety publications such as the Manufacturer's Instructions; ANSI/NFPA 70, the *National Electrical Code*; ANSI/AWS Z49.1, *Safety in Welding and Cutting*; AWS Publication C5.6-79, *Recommended Safe Practices for Gas-Metal Arc Welding*. (See 1.1, Referenced Standards.)

Scope

This Standards Publication defines minimum mechanical and electrical construction and performance requirements applying to the following arc welding power sources:

1. Single phase transformer or transformer-rectifier;
2. Polyphase transformer or transformer-rectifier;
3. DC generator;
4. AC generator or ac generator with rectifier;
5. Associated electrical attachments; and
6. Power source with integral wire feed unit.

ELECTRIC ARC WELDING POWER SOURCES

Section 1
REFERENCED STANDARDS AND DEFINITIONS

1.1 REFERENCED STANDARDS

American National Standards Institute
1430 Broadway
New York, NY 10018

Z49.1-1988	*Safety in Welding and Cutting*
C57.12.90-1987	*American National Standard Distribution Power, and Regulating Transformers, Test Code for Liquid Immersed*
C63.2-1987	*Standard for Instrumentation—Electromagnetic Noise and Field Strength, 10 KHz to 40 GHz—Specific*
C63.4-1981	*Methods of Measurement of Radio Noise Emmissions from Low-Voltage Electrical and Electronic Equipment in the 10 kHz to 1GHz Range*

American Welding Society
550 N.W. Le Jeune Road, P.O. Box 351040
Miami, FL 33135

C5.6-1979	*Recommended Safe Practices for Gas-Metal Arc Welding*

Compressed Gas Association
Crystal Gateway 1, Suite 501
1235 Jefferson Davis Highway
Arlington, VA 22202

E-1-1980	*Standard Connections For Regulator Outlets, Torches and Fitted Hose For Welding and Cutting Equipment*
E-2-1983	*Hose Link Check Valve Standards For Welding and Cutting*

Institute of Electrical and Electronics Engineers
345 E. 47th St.
New York, NY 10017

112-1984	*Standard Test Procedure for Polyphase Induction Motors and Generators*
113-1985	*Guide on Test Procedures for DC Machines*
117-1974 (R1985)	*Standard Test Procedure For Evaluation of Systems of Insulating Materials for Random-wound AC Electric Machinery*
304-1977	*Test Procedure Evaluation and Classification of Insulation System for DC Machines*

National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, D.C. 20037

WD 1-1983	*General Requirements for Wiring Devices*
EW 3-1983 (R1989)	*Semiautomatic Wire Feed Systems for Arc Welding*

National Fire Protection Association
Batterymarch Park
Quincy, MA 02269

ANSI/NFPA 70-1987	*National Electrical Code*

Rubber Manufacturers Association
1400 K Street N.W., Suite 900
Washington D.C. 20005

IP2-1987	*Hose Handbook*
IP7-1990	*Specifications for Rubber Welding Hose*

Underwriters Laboratories Inc.
333 Pfingsten Road
Northbrook, IL 60062

ANSI/UL94-1990	*Test For Flammability of Plastic Materials for Parts in Devices and Appliances*
ANSI/UL 551-1986	*Transformer-Type Arc Welding Machines*

1.2 DEFINITIONS

AC GENERATOR ARC WELDING POWER SOURCE

An ac generator arc welding power source is an ac generator with the associated control and indicating devices required to produce alternating current suitable for arc welding.

NEMA Standard 1-11-1983.

AC/DC GENERATOR-RECTIFIER ARC WELDING POWER SOURCE

An ac/dc generator-rectifier arc welding power source is a combination of an alternating current generator and static rectifiers with the associated control and indicating devices required to produce either alternating or direct current suitable for arc welding.

NEMA Standard 1-11-1983.

AC TRANSFORMER ARC WELDING POWER SOURCE

An ac transformer arc welding power source utilizes a transformer having isolated primary and secondary windings with the associated control and indicating devices required to produce an alternating current suitable for arc welding.

NEMA Standard 1-11-1983.

AC/DC TRANSFORMER-RECTIFIER ARC WELDING POWER SOURCE

An ac/dc transformer-rectifier arc welding power source is a combination of a transformer, having isolated primary and secondary windings, and static rectifiers with the associated control and indicating devices required to produce either alternating or direct current suitable for arc welding.

NEMA Standard 1-11-1983.

ARC WELDING POWER SOURCE WITH INTEGRAL WIRE FEED UNIT

An arc welding power source and wire feed unit constructed such that both are housed in a single enclosure.

NEMA Standard 11-15-1991.

ASSOCIATED ELECTRICAL ATTACHMENTS

Associated electrical attachments are those electrical controls, cables, accessories, and such, attached to the arc welding power source to facilitate control, function, or operation and that are external to the power source enclosure.

NEMA Standard 1-11-1983.

AUXILIARY POWER SUPPLY

An auxiliary power supply is a separate source of power available to the operator, which is provided by the arc welding power source for purposes other than supplying power to the welding arc.

NEMA Standard 1-11-1983.

CONSTANT CURRENT ARC WELDING POWER SOURCE

A constant current arc welding power source is a power source that has means for adjusting the load current and that has a static volt ampere curve that tends to produce a relatively constant load current. The load voltage, at a given load current, is responsive to the rate at which a consumable electrode is fed into the arc, except that, when a nonconsumable electrode is used, the load voltage is responsive to the electrode to work distance.

NEMA Standard 1-11-1983.

CONSTANT CURRENT/CONSTANT VOLTAGE ARC WELDING POWER SOURCE

A constant current/constant voltage arc welding power source is a power source that has the selectable charac-

teristics of a constant current arc welding power source or constant voltage arc welding power source.
NEMA Standard 1-11-1983.

CONSTANT VOLTAGE ARC WELDING POWER SOURCE

A constant voltage arc welding power source is a power source which has means for adjusting the load voltage and has a static volt ampere curve that produces a relatively constant load voltage. The load current, at a given load voltage, is responsive to the rate at which a consumable electrode is fed into the arc.
NEMA Standard 1-11-1983.

DC GENERATOR ARC WELDING POWER SOURCE

A dc generator arc welding power source is a dc generator with the associated control and indicating devices required to produce direct current suitable for arc welding.
NEMA Standard 1-11-1983.

DC GENERATOR-RECTIFIER ARC WELDING POWER SOURCE

A dc generator-rectifier arc welding power source is a combination of an ac generator and static rectifiers with the associated control and indicating devices required to produce direct current suitable for arc welding.
NEMA Standard 1-11-1983.

DC TRANSFORMER-RECTIFIER ARC WELDING POWER SOURCE

A dc transformer-rectifier arc welding power source is a combination of a transformer, having isolated primary and secondary windings, and static rectifiers with the associated control and indicating devices required to produce direct current suitable for arc welding.
NEMA Standard 1-11-1983.

DUTY CYCLE

Duty cycle, expressed in percent, is the ratio of arc time to total time.

For the purpose of these standards, the time period of one complete test cycle shall be 10 minutes. (For example, in the case of a 60 percent duty cycle, load shall be applied continuously for 6 minutes and shall be off for 4 minutes.)
NEMA Standard 1-24-1962.

EFFICIENCY

The efficiency of an arc welding power source is the ratio of the power output at the welding terminals to the total power input. Unless otherwise specified, the efficiency shall be given when the power source is operated at rated output.
NEMA Standard 1-11-1983.

ENCLOSURE

An arc welding power source enclosure is the surrounding case or housing constructed to provide a degree of protection to personnel against incidental contact with energized and moving parts and to provide a degree of protection to the power source against damage that will adversely affect its operation.
NEMA Standard 1-11-1983.

ELECTRODE LEAD

An electrode lead is the welding lead between one of the welding terminals of the arc welding power source and the welding electrode.
NEMA Standard 1-11-1983.

ENGINE GENERATOR ARC WELDING POWER SOURCE

An engine generator arc welding power source is a power source that consists of an engine mechanically connected to, and mounted with, one or more arc welding generators.
NEMA Standard 1-11-1983.

FRAME

The frame of an arc welding power source is a supporting structure provided to increase the strength and rigidity of the enclosure, and to provide means for mounting the various parts of the power source, or both.
NEMA Standard 1-11-1983.

HAND-HELD ASSEMBLY

An assembly or device that is designed to be supported and manipulated by hand during use.
NEMA Standard 1-11-1983.

HIGH FREQUENCY STABILIZED ARC WELDING POWER SOURCE

A high frequency stabilized arc welding power source is a constant current arc welding power source that includes a high-frequency arc stabilizer as an integral part of the power source and the suitable controls required to produce welding current. It is primarily intended for gas tungsten-arc welding.
NEMA Standard 1-11-1983.

INPUT CURRENT

Input current is the amperage drawn from the electrical power supply to operate an arc welding power source.
NEMA Standard 1-11-1983.

INPUT RATING

For an arc welding power source operating from an electrical power supply, the input rating consists of the rated input voltage(s), number of phases, rated frequency(s), and the input current when the power source is delivering rated output.
NEMA Standard 1-11-1983.

JACK

A female contact device designed to mate with a jack plug to establish an electrical connection.
NEMA Standard 1-11-1983.

JACK PLUG

A male device, usually associated with welding lead(s), that is inserted into a jack to establish an electrical connection of the welding circuit.

NEMA Standard 1-11-1983.

LIVE PART

A live part is a part at a potential different from ground, which could render an electrical shock.

NEMA Standard 11-17-1988.

LOAD CURRENT

The load current is the amperage flowing in the welding circuit when a load is applied to the welding terminals.

NEMA Standard 1-11-1983.

LOAD VOLTAGE

Load voltage is the voltage between the welding terminals of the arc welding power source when load current is flowing in the welding circuit.

NEMA Standard 1-11-1983.

MOTOR GENERATOR ARC WELDING POWER SOURCE

A motor generator arc welding power source is a power source that consists of an electric motor mechanically connected to and mounted with one or more arc welding generators.

NEMA Standard 1-11-1983.

MULTIPLE OPERATOR ARC WELDING POWER SOURCE

A multiple operator arc welding power source is a power source that supplies two or more welding arcs through suitable output control devices without objectionable arc interaction.

NEMA Standard 1-11-1983.

MULTIPLE OPERATOR WELDING OUTLET

A multiple operator welding outlet is a control station containing an adjustable output control device for adjusting load current supplied from a multiple operator arc welding power source.

NEMA Standard 1-11-1983.

NEMA CLASS I ARC WELDING POWER SOURCE

A NEMA Class I arc welding power source is characterized by its ability to deliver rated output at duty cycles of 60, 80, or 100 percent. If a power source is manufactured in accordance with the applicable standards for Class I power sources in this publication, it shall be marked "NEMA Class I (60)", "NEMA Class I (80)", or "NEMA Class I (100)".

A NEMA Class I arc welding power source is a completely assembled arc welding power source that is comprised of the characteristics listed below:

1. A constant current power source, a constant voltage power source, or a constant current/constant voltage power source, and;
2. A single operator power source, and;
3. One of the following:
   a. DC generator arc welding power source;
   b. AC generator arc welding power source;
   c. DC generator-rectifier arc welding power source;
   d. AC/DC generator-rectifier arc welding power source;
   e. AC transformer arc welding power source;
   f. DC transformer arc welding power source;
   g. AC/DC transformer-rectifier arc welding power source.

NEMA Standard 1-11-1983.

NEMA CLASS II ARC WELDING POWER SOURCE

A NEMA Class II arc welding power source is characterized by its ability to deliver rated output at duty cycles of 30, 40, or 50 percent. If a power source is manufactured in accordance with the applicable standards for Class II power sources in this publication, it shall be marked "NEMA Class II (30)", "NEMA Class II (40)", or "NEMA Class II (50)".

A NEMA Class II arc welding power source is a completely assembled arc welding power source which is comprised of the characteristics listed below:

1. A constant current power source, a constant voltage power source, or a constant current/constant voltage power source, and;
2. A single operator power source, and;
3. One of the following:
   a. DC generator arc welding power source;
   b. AC generator arc welding power source;
   c. DC generator-rectifier arc welding power source;
   d. AC/DC generator-rectifier arc welding power source;
   e. AC transformer arc welding power source;
   f. DC transformer arc welding power source;
   g. AC/DC transformer-rectifier arc welding power source.

NEMA Standard 1-11-1983.

NEMA CLASS III ARC WELDING POWER SOURCE

A NEMA Class III arc welding power source is characterized by its ability to deliver rated output at a duty cycle of 20 percent. If a power source is manufactured in accordance with the applicable standards for Class III power sources in this publication, it shall be marked "NEMA Class III (20)".

A NEMA Class III arc welding power source is a completely assembled arc welding power source that is comprised of the characteristics listed below:

1. A constant current power source; and
2. A single operator power source; and

3. One of the following:
   a. AC transformer arc welding power source;
   b. DC transformer-rectifier arc welding power source;
   c. AC/DC transformer-rectifier arc welding power source.

NEMA Standard 1-11-1983.

OPEN CIRCUIT VOLTAGE

Open circuit voltage is the voltage, excluding high frequency stabilization voltage, between the welding terminals of the arc welding power source when no load current is flowing in the welding circuit.

NEMA Standard 1-11-1983.

PERCENT RIPPLE VOLTAGE

Percent ripple voltage is the ratio, expressed as a percentage, of the effective (root mean square) value of the ripple voltage to the average value of a pulsating unidirectional voltage. The root-mean-square value of the ripple voltage may be measured with a root-mean-square indicating meter in series with a capacitor having sufficiently low impedance so as not to affect appreciably the indication of the voltmeter. Rectifier type instruments should not be used.

Authorized Engineering Information 5-14-1970.

RATED FREQUENCY

Rated frequency (expressed in hertz) is the supply voltage frequency at which an arc welding power source is designed to operate.

NEMA Standard 1-11-1983.

RATED INPUT VOLTAGE

The rated input voltage is the supply voltage(s) at which an arc welding power source is designed to operate.

NEMA Standard 1-11-1983.

RATED LOAD CURRENT

The rated load current is the load current at rated output.

NEMA Standard 1-11-1983.

RATED LOAD SPEED

The rated load speed of an arc welding power source is the rotational speed at which an arc welding generator is designed to operate when delivering rated output.

NEMA Standard 1-11-1983.

RATED LOAD VOLTAGE

Rated load voltage is the load voltage at rated output.

NEMA Standard 1-11-1983.

RATED OUTPUT

The rated output of an arc welding power source shall consist of a designated limit of output or capacity expressed as rated load voltage, rated load current, and rated duty cycle when the power source is operated at rated input voltage(s) and rated frequency(s), or at rated load speed.

NEMA Standard 1-11-1983.

SERVICE LINE HOSES

Service line hoses are the hoses external to the enclosure to or from an arc welding power source, including connectors, supplying shielding medium, cooling medium, and providing means for fume removal, and/or nonelectrical power or control.

NEMA Standard 11-15-1991.

SINGLE OPERATOR ARC WELDING POWER SOURCE

A single operator arc welding power source is a power source which is designed to deliver load current to only one welding arc.

NEMA Standard 1-11-1983.

SLOPE OF THE STATIC VOLT AMPERE CURVE

The slope of the static volt ampere curve is the ratio of load voltage change to the change in load current expressed in volts per 100 amperes.

NEMA Standard 7-14-1971.

STATIC VOLT AMPERE CHARACTERISTICS

The static volt ampere characteristics is the curve or family of curves which gives the steady state load voltage of an arc welding power source as ordinate, plotted against the steady state load current as abscissa.

NEMA Standard 1-11-1983.

WELDING CIRCUIT

The welding circuit consists of all attachments connected to the welding terminals of the arc welding power source.

NEMA Standard 1-11-1983.

WELDING LEADS

Welding leads conduct the welding power and, when provided, high frequency energy from the welding terminals to the welding arc.

NEMA Standard 1-11-1983.

WELDING TERMINALS

Welding terminals are those terminals of an arc welding power source which furnish welding power and, when provided, high frequency energy for the welding arc.

NEMA Standard 1-11-1983.

WORK LEAD

A work lead is the welding lead between one of the welding terminals of the arc welding power source and the work.

NEMA Standard 1-11-1983.

Section 2
GENERAL

2.1 SUITABILITY OF OPERATION

The characteristics of an arc welding power source conforming to these standards shall be such that a qualified operator, or appropriate mechanically controlled equipment, can, by following the manufacturer's recommended installation and operating procedures, weld satisfactorily within the specified operating range of the power source and with the welding processes for which it is intended to be used.

NEMA Standard 1-11-1983.

2.2 ARC WELDING POWER SOURCE WITH INTEGRAL WIRE FEED UNIT

A wire feed unit included with the power source shall comply with NEMA EW 3. The provisions of EW 3 shall be in addition to and not in place of the provision of EW 1.

NEMA Standard 11-15-1991.

2.3 SERVICE CONDITIONS

Service conditions, other than those specified as usual, may have some detrimental effect on the arc welding power source. Such effect depends upon the degree of departure from usual operating conditions and the severity of the environment to which the power source is exposed. Of principal concern are unusual service conditions which may cause abnormal deterioration of the insulation system, electrical breakdown, or mechanical wear, resulting in premature failure. The manufacturer of the power source should be consulted for further information regarding any unusual service conditions.

Authorized Engineering Information 1-11-1983.

2.4 USUAL SERVICE CONDITIONS

An arc welding power source constructed in accordance with these standards shall be capable of operation, when the following conditions prevail:

1. Where the ambient temperature is in the range of 0°C to 40°C;
2. Where the altitude is between sea level and 3300 feet (1000 meters);
3. When exposed to gases and dust only to the extent of those normally produced by the welding arc;
4. When the input line voltage varies within the range of ±10 percent of input line voltage rating of the arc welding power source; and
5. Where the base of a power source is within 15 degrees of horizontal.

NEMA Standard 1-11-1983.

2.5 UNUSUAL SERVICE CONDITIONS

Examples of unusual service conditions are exposure to:

1. Combustible or conducting dusts;
2. Chemical fumes or flammable gases;
3. Rain, steam, or oil vapor;
4. Vermin infestation or atmosphere conducive to the growth of fungus;
5. Very dirty, corrosive, explosive, or abrasive environment;
6. High radiant or conducted heat;
7. Abnormal shock or vibration;
8. Nuclear radiation;
9. Severe weather conditions;
10. Seacoast and shipboard conditions;
11. Continuous average relative humidity above 90 percent or below 10 percent; or
12. Altitudes in excess of 3300 feet (1000 meters).

Authorized Engineering Information 1-11-1983.

2.6 INSTALLATION AND OPERATION

Arc welding power sources shall be installed and operated in accordance with the *National Electrical Code*, state and local codes as applicable, the manufacturers instructions, and applicable safety specifications.

NEMA Standard 11-17-1988.

Section 3
CONSTRUCTION REQUIREMENTS—MECHANICAL CONSIDERATIONS

3.1 FRAME AND ENCLOSURE

An arc welding power source shall be so formed and assembled that it will have the strength and rigidity necessary to withstand the normal service to which it is likely to be subjected without increasing its shock, fire, or other hazard. An arc welding power source shall be provided with a case or cabinet that shall enclose all current carrying parts and hazardous moving parts (such as motors, pulleys, belts, fans, gears, and such) except that the following need not be enclosed:

1. A flexible supply cord or cable and welding leads; and
2. Ungrounded output terminals for the connection of welding leads, jack plugs, jacks, or similar parts connected to the output circuit and limited in open circuit voltage in accordance with 5.3 if they are suitably protected against unintentional contact.

NEMA Standard 1-11-1983.

Protection will usually be afforded if: (a) jacks and uninsulated current carrying parts of the power source, including the specified output terminal lugs in the case of threaded type connections, are recessed behind the vertical plane of the access opening; (b) an uninsulated current carrying part of the power source is recessed for a distance not less than one half of the minimum dimension of the opening behind which the current carrying part is located; or (c) a hinged cover, or a protective guard or cover, which is removable only by the use of tools, with smooth edged slots or openings for the cable is provided over the terminals.

Authorized Engineering Information 1-11-1983.

3.2 ENCLOSURE CONSTRUCTION

3.2.1 An enclosure shall be constructed of either sheet metal, cast metal, or a nonmetallic material. If the enclosure is constructed from sheet metal, the thickness shall not be less than that given in Tables 3-1 or 3-2 (see also 3.2.2). These tables are based on a uniform deflection of the enclosure surface for any given load concentrated at the center of the surface regardless of metal thickness. The thickness of a cast metal enclosure shall be not less than that given in Table 3-3. If the enclosure is constructed of nonmetallic material, the material shall conform to Class 94V-0 of ANSI/UL 94, *Test for Flammability of Plastic Materials for Parts in Devices and Appliances.* The enclosure shall have a mechanical strength at least equivalent to a sheet metal enclosure constructed in accordance with Table 3-1 or 3-2.

3.2.2 The thickness of sheet metal in an area where provision is made for connection of a wiring system in the field shall not be less than 0.053 inch (1.35 mm) if uncoated steel, 0.056 inch (1.42 mm) if galvanized steel and not less than 0.075 inch (1.91 mm) for aluminum, copper, and brass.

3.2.3 Construction of the power source enclosure shall be such that there are no sharp projections or edges on the exposed exterior surfaces of the enclosure that are likely to cause accidental injury to personnel.

NEMA Standard 1-11-1983.

3.2.4 Among the factors to consider in determining the suitability of an enclosure are its: (1) physical strength, (2) resistance to impact, (3) moisture absorptive properties, (4) combustibility, (5) resistance to corrosion, (6) resistance to distortion at temperatures to which the enclosure may be subjected under conditions of normal or abnormal use, and (7) resistance to ignition from electrical sources. For a nonmetallic enclosure, all of these factors are considered with respect to thermal aging.

3.2.5 With reference to Tables 3-1 and 3-2, a supporting frame is a structure of angle or channel or a folded rigid section of sheet metal that is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and has sufficient torsional rigidity to resist the bending moments that may be applied to the surface of the enclosure when it is deflected. Construction that is considered to have equivalent reinforcing may be accomplished by designs that will produce a structure that is as rigid as one built with a frame of angles or channels.

3.2.6 Construction considered to be without supporting frame includes: (a) single sheet with single formed flanges (formed edges), (b) a single sheet that is corrugated or ribbed, (c) an enclosure surface loosely attached to a frame (for example, with spring clips), or (d) an enclosure formed or fabricated from sheet metal.

3.2.7 The minimum thickness of an enclosure without supporting frame may be less than shown in Tables 3-1, 3-2, and 3-3 if the enclosure is so reinforced that if subjected to bending and torsion forces, its strength and rigidity are shown to be not less than the corresponding properties of an enclosure of the same maximum length and width having the required thickness of metal.

Authorized Engineering Information 1-11-1983.

3.3 OPENINGS IN ENCLOSURES

The suitability of an opening in the enclosure of an arc welding power source shall be determined in accordance with 3.3.1 or 3.3.2, except that for engine or motor driven power sources, the suitability of the openings shall be determined in accordance with 3.3.3. Any part of the outer enclosure that is intended to be opened or removed without the use of tools by the user of the equipment (to permit the attachment of accessories, to allow access to means for making operating adjustments, or for other reasons) shall be opened or removed prior to examination.

3.3.1 Openings In Other Than Hand-Held Arc Welding Power Source Assemblies

1. An opening that will not permit entrance of 0.750 inch (19 mm) diameter rod shall be suitable if a 0.500 inch (12.7 mm) diameter (D) probe, illustrated in Figure 3-1, cannot be made to touch film-coated wire, uninsulated live part(s), hazardous moving part(s) or any combination thereof, when it is inserted with a one pound force (4.45 N) through the opening.

NEMA Standard 1-11-1983.

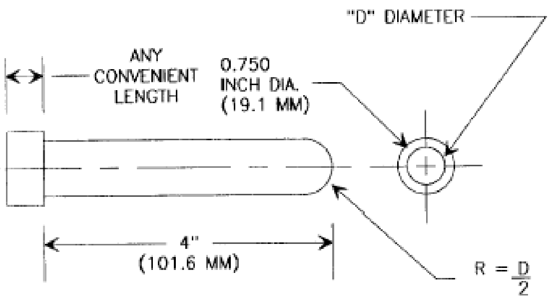

Figure 3-1
PROBE

2. An opening that will permit entrance of a 0.750 inch (19 mm) diameter rod shall be suitable if there is no film-coated wire, uninsulated live part(s), hazardous moving part(s) or any combination thereof; (1) less than X inches (X mm) from the perimeter of the opening, and; (2) within the volume generated by projecting the perimeter X inches (X mm) normal to its plane when X equals five times the diameter of the largest diameter rod (but not less than 4 inches (101.6 mm) that can be inserted through the opening. See Figure 3-2.

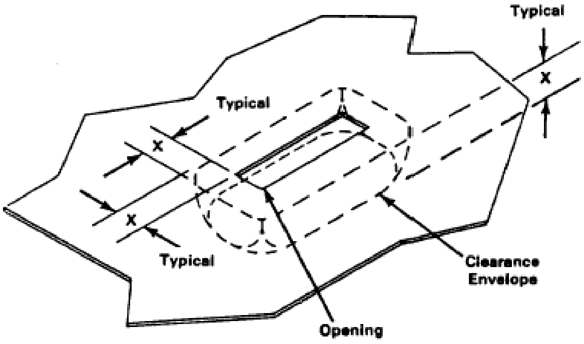

Figure 3-2
ENCLOSURE OPENING

3.3.2 Openings in Hand Held Arc Welding Power Source Assemblies

An opening in a hand-held assembly shall be suitable if a 0.375 inch (9.5 mm) diameter (D) probe, illustrated in Figure 3-1, when inserted into the opening to a maximum of 1 inch (25.4 mm) cannot be made to touch any film-coated wire, uninsulated live part(s), hazardous moving part(s), or any combination thereof.

3.3.3 Openings in Engine or Motor Driven Power Sources

Openings in the enclosures for engine or motor driven power sources shall provide protection in accordance with 3.3.1 and 3.3.2. Where in service access to the equipment is required and enclosure protection cannot reasonably be assured, a label calling attention to any potential hazard shall be prominently displayed on the equipment.

NEMA Standard 1-11-1983.

3.4 CORROSION PROTECTION

All metallic parts shall be painted, plated, or otherwise protected against corrosion if the deterioration of such unprotected parts would be likely to result in a hazardous condition.

NEMA Standard 1-11-1983.

3.5 SERVICE LINE HOSES

If supplied as part of the arc welding power source, service line hoses and hose connections shall comply with Rubber Manufacturers Association Inc. Publication No. IP-7, *Specification for Rubber Welding Hose*, or IP-2, *Hose Handbook*, and Compressed Gas Association Inc. Publication No. E1, *Standard Connections for Regulators, Outlets, Torches, and Fitted Hose for Welding and Cutting Equipment*, or E-2, *Hose Line Check Value Standards for Welding and Cutting*.

NEMA Standard 11-17-1988.

3.6 WATER COOLING

Any device or system using water for cooling, other than an integrated recirculating system, shall be capable of operating at an inlet water pressure ranging from 30 psi (207 kPa) to 75 psi (517 kPa) and a water inlet temperature up to 49°C. For rating purposes, the water inlet pressure shall be 30 psi (207 kPa) at a water inlet temperature of 49°C.

3.7 BRUSHES

Brushes used as part of the arc welding power source shall be in accordance with ANSI/NEMA Standards Publication No. CB 1, *Brushes for Electrical Machines*.

NEMA Standard 11-15-1991.

3.8 JERK AND DROP TESTS

3.8.1 Jerk Test

If an eye or lug is provided for the purpose of lifting an assembled arc welding power source, such device shall be capable of withstanding a free fall jerk test. This test shall be made with the power source equipped with all associated attachments (excluding trailers, carts, and wheel running gears) that are likely to be installed and, in the case of engine driven power sources, completely serviced and ready for operation.

The unit shall be suspended from a rigid member by a chain or cable attached to the lifting eye or lug, and it shall be positioned for a direct free fall. The chain or cable suspension assembly shall be arranged to provide for a free fall of at least 6 inches (152 mm) before the unit is caught in suspension bringing the full force of the fall to bear on the lifting eye or lug. Three such falls shall be made.

3.8.2 Drop Test

An assembled arc welding power source equipped with all associated attachments (excluding trailers, carts, and wheel running gear) that are likely to be installed and, in the case of engine driven power sources completely serviced and ready for operation, shall be capable of withstanding a drop test. This test shall consist of three drops onto a hard and rigid surface from a height of not less than 6 inches (152 mm). These drops shall be so arranged that each drop shall strike on a bottom edge different from that of any other drop.

3.8.3 Test Conformance

After the above tests, the power source shall still conform to the provisions of this standard, other than the foregoing 3.8.1 and 3.8.2, in all respects even though there may be some deformation of the structural parts of enclosure.

NEMA Standard 1-11-1983.

3.9 STACKING OF ARC WELDING POWER SOURCES

If the manufacturer represents a power source for stacking, its enclosure, with all panels securely in place, shall be manufactured so that it will have the strength and rigidity to support the manufacturer's specified number and types of additional arc welding power sources. The locating means for stacking the arc welding power sources shall be such that the lower units cannot be lifted by the lifting yoke or eye of the top arc welding power source, unless the manufacturer represents that all of the power sources can be lifted as a unit.

NEMA Standard 1-11-1983.

Table 3-1
MINIMUM THICKNESS OF SHEET METAL FOR ENCLOSURES—
CARBON STEEL OR STAINLESS STEEL

Without Supporting Frame(a)				With Supporting Frame or Equivalent Reinforcing (b)				Minimum Thickness			
Maximum Width(c), Inches (mm)		Maximum Length(d) of Supported Edge, Inches (mm)		Maximum Width(c), Inches (mm)		Maximum Length, Inches (mm)		Uncoated, Inches (mm)		Zinc Coated Inches (mm)	
4.0	(102)	Not limited		6.25	(159)	Not limited					
4.75	(121)	5.75	(146)	6.75	(171)	8.25	(210)	0.020	(0.51)	0.023	(0.58)
6.0	(152)	Not limited		9.5	(241)	Not limited					
7.0	(179)	8.75	(222)	10.0	(254)	12.5	(318)	0.026	(0.66)	0.029	(0.74)
8.0	(203)	Not limited		2.0	(305)	Not limited					
9.0	(229)	11.5	(292)	13.0	(330)	16.0	(406)	0.032	(0.81)	0.034	(0.86)
12.5	(318)	Not limited		19.5	(495)	Not limited					
14.0	(356)	18.0	(457)	21.0	(533)	25.0	(635)	0.042	(1.07)	0.045	(1.14)
18.0	(457)	Not limited		27.0	(686)	Not limited					
20.0	(508)	25.0	(635)	29.0	(737)	36.0	(914)	0.053	(1.35)	0.056	(1.42)
22.0	(559)	Not limited		33.0	(838)	Not limited					
25.0	(635)	31.0	(787)	35.0	(889)	43.0	(1092)	0.060	(1.52)	0.063	(1.60)
25.0	(635)	Not limited		39.0	(991)	Not limited					
29.0	(737)	36.0	(914)	41.0	(1041)	51.0	(1295)	0.067	(1.70)	0.070	(1.78)
33.0	(838)	Not limited		51.0	(1295)	Not limited					
38.0	(965)	47.0	(1194)	54.0	(1372)	66.0	(1676)	0.080	(2.03)	0.084	(2.13)
42.0	(1067)	Not limited		64.0	(1626)	Not limited					
47.0	(1194)	59.0	(1499)	68.0	(1727)	84.0	(2134)	0.093	(2.36)	0.097	(2.46)
52.0	(1321)	Not limited		80.0	(2032)	Not limited					
60.0	(1524)	74.0	(1880)	84.0	(2134)	103.0	(2616)	0.108	(2.74)	0.111	(2.82)
63.0	(1606)	Not limited		97.0	(2464)	Not limited					
73.0	(1854)	90.0	(2286)	103.0	(2616)	127.0	(3226)	0.123	(3.12)	0.126	(3.20)

[a] See 3.2.6

[b] See 3.2.5

[c] The width is the smaller dimension of a rectangular piece of sheet metal that is part of an enclosure. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.

[d] Not limited applies only if the edge of the surface is flanged at least 0.500 inch (12.7 mm) or fastened to adjacent surfaces not normally removed in use.

Table 3-2
MINIMUM THICKNESS OF SHEET METAL FOR ENCLOSURES – ALUMINUM, COPPER, OR BRASS

Without Supporting Frame(a)				With Supporting Frame or Equivalent Reinforcing (b)				Minimum Thickness	
Maximum Width(c), Inches (mm)		Maximum Length(d) of Supported Edge, Inches (mm)		Maximum Width(c), Inches (mm)		Maximum Length, Inches (mm)		Uncoated, Inches (mm)	
3.0	(76)	Not limited		7.0	(179)	Not limited			
3.5	(90)	4.0	(102)	8.5	(216)	9.5	(241)	0.023	(0.58)
4.0	(102)	Not limited		10.0	(254)	Not limited			
5.0	(127)	6.0	(152)	10.5	(267)	13.5	(343)	0.029	(0.74)
6.0	(152)	Not limited		14.0	(356)	Not limited			
6.5	(165)	8.0	(203)	15.0	(381)	18.0	(457)	0.036	(0.91)
8.0	(203)	Not limited		19.0	(483)	Not limited			
9.5	(241)	11.5	(292)	21.0	(533)	25.0	(635)	0.045	(1.14)
12.0	(305)	Not limited		28.0	(711)	Not limited			
14.0	(356)	16.0	(406)	30.0	(762)	37.0	(940)	0.058	(1.47)
18.0	(457)	Not limited		42.0	(1067)	Not limited			
20.0	(508)	25.0	(635)	45.0	(1143)	55.0	(1397)	0.075	(1.90)
25.0	(635)	Not limited		60.0	(1524)	Not limited			
29.0	(737)	36.0	(914)	64.0	(1626)	78.0	(1981)	0.095	(2.41)
37.0	(939)	Not limited		87.0	(2210)	Not limited			
42.0	(1067)	53.0	(1346)	93.0	(2362)	114.0	(2896)	0.122	(3.10)
52.0	(1321)	Not limited		123.0	(3124)	Not limited			
60.0	(1524)	74.0	(1880)	130.0	(3302)	160.0	(40634)	0.153	(3.89)

(a) See par. 3.2.6

(b) See par. 3.2.5

(c) The width is the smaller dimension of a rectangular piece of sheet metal that is part of an enclosure. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.

(d) Not limited applies only if the edge of the surface is flanged at least 0.500 inch (12.7 mm) or fastened to adjacent surfaces not normally removed in use.

Table 3-2 data are reprinted by permission of Underwriters Laboratories from ANSI/UL 551.

Table 3-3
MINIMUM THICKNESS OF CAST METAL FOR ENCLOSURES

Dimensions or Location or Area Involved	Minimum Thickness			
	Cast Metal Other Than Die-Cast		Die-Cast Metal	
	Inches	(mm)	Inches	(mm)
Area of 24 square inches (154.8 = square cm) or less and having no dimension greater than 6 inches (152 mm)	0.125	(3.18)	0.062[a]	(1.59)
Area greater than 24 inches squared (154.8 cm squared) or having any dimension greater than 6 inches (152 mm)	0.125	(3.18)	0.094	(2.38)
At a threaded conduit hole	0.250	(6.15)	0.250	(6.35)
At an unthreaded conduit hole	0.125	(3.18)	0.125	(3.18)

[a]The area limitation for metal 0.062 inch (1.59 mm) thick can be obtained by the provision of suitable reinforcing ribs subdividing a larger area.

Table 3-3 data are reprinted by permission of Underwriters Laboratories from ANSI/UL-551.

Section 4
CONSTRUCTION REQUIREMENTS – ELECTRICAL CONSIDERATIONS

4.1 POWER SUPPLY CONNECTION – GENERAL

Where power supply conductors pass through an opening in a barrier or enclosure, the edges of the opening shall be smoothly rounded or shall be provided with a secured and smooth rounded bushing.

The ampacity used for conductor selection shall be calculated from the following equation:

$$I_r = \sqrt{I_a^2 d + I_b^2(1-d)}$$

Where:
I_r = Ampacity requirements in amperes.
I_a = Nameplate input current at rated voltage and at rated output.
I_b = Input current at rated input voltage and at no load

$$d = \frac{\text{Rated Duty Cycle (Percent)}}{100}$$

When a flexible cord is used for power supply connection, it shall be sized in accordance with Table 4-1. Where wiring terminals or terminal leads are provided, they shall be suitable for the connection of power supply conductors which are sized in accordance with Table 4-2.

NEMA Standard 11-17-1988.

Table 4-1
CONDUCTOR SIZE OF CORDS

Required Ampacity (I_r) [a]		Conductor Size, AWG
Two Conductor	Three Conductor	
10	7	18
13	10	16
18	15	14
25	20	12
30	25	10
40	35	8
55	45	6
70	60	4
95	80	2

[a] The ampacities are applicable to current carrying conductors in accordance with Table 400-5 of the **1987 National Electrical Code.** The ampacities listed above are based upon a 30°C ambient temperature. A conductor used for equipment grounding is not considered to be a current carrying conductor.

Table 4-2
SIZE OF INSULATED COPPER CONDUCTORS (Not More Than Three Conductors in Raceway or Cable)

Required Ampacity (I_r)[a]	Conductor Size, AWG	Required Ampacity (I_r)[a]	Conductor Size, AWG
15	14	150	0
20	12	175	00
30	10	200	000
50	8	230	0000
65	6	255	250 kcmil
85	4	285	300 kcmil
100	3	310	350 kcmil
115	2	335	400 kcmil
130	1	380	500 kcmil

[a] The ampacities in Table 4-2 are based upon 75°C temperature rating of conductors with ampacities in accordance with Table 310-16 of the **1987 National Electrical Code.** Ampacities listed above are based upon a 30°C ambient temperature. A conductor used for equipment grounding is not considered to be a current carrying conductor.

4.2 POWER SUPPLY BY FLEXIBLE CORD

When a flexible cord is used as a part of the power source for power supply connection, it shall be a type S, SO, ST, or STO except that a NEMA Class III power source may, alternatively, be provided with a Type SJ, SJO, SJT, SJTO, or SPT-3 flexible cord. Such flexible cords shall not be less than 5 feet (1.52 meters) in length as measured from the strain relief provided at the enclosure of the power source to the attachment plug terminal provided for connection to the power supply receptacle.

A NEMA Class III power source that has wheels, casters, or other obvious means of mobility shall be equipped with a flexible cord. An attachment plug shall be provided on the flexible cord and it shall be selected to conform to NEMA Standards Publication No. WD 1, *General-Purpose Wiring Devices,* for the input voltage and current rating of the power source. The attachment plug terminating the flexible cord shall be of the grounding type. When a NEMA Class III power source is provided with a switch or circuit breaker that complies with the requirements of 4.10.3, the rating of the attachment plug shall not be less than 75 percent of the input current rating of the power source.

Flexible cords shall be provided with strain relief so that an external pulling force, as specified in Table 4-3, exerted for one minute on the flexible cord from any direction will not be transmitted to the terminals, splices, or internal wiring of the power source.

Means shall be provided to prevent the flexible cord from being pushed into the enclosures through the cord entry hole if such displacement is likely to: (1) subject the cord to mechanical damage, (2) expose the cord to a temperature higher than that for which it is intended, or (3) reduce spacings (such as to a metal strain relief clamp) below those specified in Table 4-5.

NEMA Standard 1-11-1983.

Table 4-3
EXTERNAL PULLING FORCE

Wire Size	Pulling Force	
AWG	Lbs.	N
16–18	35	155.9
12–14	50	222.4
10–Larger	100	444.8

4.3 POWER SUPPLY BY PERMANENT WIRING SYSTEM

If a power source is not provided with a flexible cord for power supply connection, it shall be provided with input wiring terminals or input terminal leads which shall be enclosed and accessible only by means of tools. A hole, knockout, or fitting shall be provided to facilitate connection to a permanent wiring system. The diameter and the size of the flat surface surrounding a hole or knockout shall conform to Table 4-4.

NEMA Standard 1-11-1983.

4.4 GROUNDING

All exposed noncurrent carrying conductive parts, which might become energized under the rigors of normal use and handling shall have metal-to-metal contact or shall be otherwise electrically bonded together and connected to a common grounding means.

The grounding means shall be:

1. A part of the power source;
2. Used only for grounding purposes;
3. Unlikely to be disassembled during operation or servicing;
4. Of adequate size for the grounding conductor as specified in accordance with Table 250-95 and article 250-51(2) of the *1987 National Electrical Code;* and
5. Located in the vicinity of the supply connections.

The grounding means shall be a metal stud, binding post, pressure connector, binding screw, uninsulated or insulated leads, internally threaded boss, or equivalent means. Solder alone shall not be relied upon as a means for grounding connections.

When the grounding means is an insulated lead, it shall have a green colored surface with or without one or more yellow stripes. In all other cases, the grounding means shall be identified by green coloring or by a legible marking with the symbols ⏚ or (⏚), alternatively, with the letter(s) G, GR, GRD, GND or GROUND.

NEMA Standard 1-11-1983.

4.5 CORROSION PROTECTION

When materials subject to corrosion, such as iron, steel, or aluminum, etc., are used as part of the wiring terminal or grounding means, such parts shall be plated or otherwise protected to maintain the integrity of the electrical connection.

NEMA Standard 1-11-1983.

Table 4-4
DIAMETER OF KNOCKOUT OR HOLE FOR CONDUIT AND WIDTH OF SURROUNDING FLAT SURFACE

Size of Supply Conductor, AWG		Trade Size Conduit Nom.	Knockout Clearance Hole					
			Minimum		Nominal		Maximum	
Single Phase	Three Phase		Inches	(mm)	Inches	(mm)	Inches	(mm)
14–10	14–10	½	0.859	(21.82)	0.875	(22.22)	0.906	(23.01)
8	8	¾	1.094	(27.79)	1.109	(28.17)	1.141	(28.98)
6–4	6–4	1	1.359	(34.52)	1.375	(34.92)	1.406	(35.17)
3–1	3–2	1¼	1.719	(43.66)	1.734	(44.04)	1.766	(44.86)
1/0–2/0	1–1/0	1½	1.958	(49.73)	1.984	(50.39)	2.016	(51.21)
3/0–4/0	2/0–3/0	2	2.433	(61.80)	2.469	(62.71)	2.500	(63.50)
250–300 kcmil	4/0–200 kcmil	2½	2.938	(74.62)	2.969	(75.41)	3.000	(76.20)

Table 4-5
SPACINGS IN ARC WELDING POWER SOURCES[(a)]

r.m.s. Voltage Between Parts Involved (d, e)	At Wiring Terminals (b)				At Other Than Wiring Terminals							
					To other than Enclosure Walls				To walls of a metal enclosure (f, g)			
	Through Air		Over Surface		Through Air (c)		Over Surface		Through Air		Over Surface	
	In.	(mm)	In.	(mm)	In.	(mm)	In.	(mm)	In.	(mm)	In.	(mm)
0 – 50	½	(12.7)	½	(12.7)	⅛	(3.18)	⅛	(3.18)	½	(12.7)	½	(12.7)
51 – 150	½	(12.7)	½	(12.7)	⅛	(3.18)	¼	(6.35)	½	(12.7)	½	(12.7)
151 – 300	½	(12.7)	½	(12.7)	¼	(6.35)	⅜	(9.53)	½	(12.7)	½	(12.7)
301 – 600	1	(25.4)	1	(25.4)	⅜	(9.53)	½	(12.7)	½	(12.7)	½	(12.7)

[(a)] Values do not apply to a turn of wire on a coil or to spacings between (1) two conductors of a coil, (2) a coil and its core, and (3) a coil and any other part of opposite polarity including the crossover lead. The spacings given in Table 4-5 do not apply to wiring devices (snap switches, lampholders, etc.), motors, printed circuit boards and devices, or other accessories for which there are standards established for such components.

[(b)] Wiring terminals are considered to be terminals to which supply connections are made in the field.

[(c)] The spacing between screw type terminals of opposite polarity shall be not less than 0.250 inch (6.35 mm) if the terminals are in the same plane.

[(d)] When the repetitive peak voltage on which the device is used is more than 1.5 times the rms volts, the peak voltage shall be divided by 2 to obtain an equivalent rms rating in volts.

[(e)] For grounded power systems, such as three phase four wire systems, the clearance and creepage distances to ground shall be governed by voltage to ground.

[(f)] A metal piece attached to the enclosure is considered to be a part of the enclosure if deformation of the enclosure is likely to reduce clearance and creepage distances between the metal piece and uninsulated live parts or film coated wire.

[(g)] For subassembly enclosures where clearance and creepage distances are rigidly maintained and when mounted inside another enclosure, the distances for "to other than enclosure walls" shall be permitted instead of "to walls of metal enclosure" but in no case shall they be less than 0.100 inch (2.54 mm).

4.6 OUTPUT PROVISIONS

4.6.1 Welding Leads

Welding leads supplied with the power source shall be of a size sufficient to limit the temperature to 85°C or to the temperature rating of the cable insulation, whichever is less, when operated at the rated load current and duty cycle of the power source.

When welding leads are supplied as integral parts of the power source, the attachment of such leads shall be so constructed to withstand an external pull, exerted for 1 minute from any direction, as specified in Table 4-3, without reducing electrical spacings below those specified in Table 4-5, or causing damage to any internal parts of the power source. However, the pull applied to the welding leads need not be more than that specified for the flexible cord used for the power supply connection.

At locations where a welding lead passes through an opening in a barrier, or enclosure, the opening shall be smoothly rounded or shall be provided with a secured and smoothly rounded bushing.

For a power source with integral wire feed unit, the provisions of EW 3 shall apply for the gun cable assembly.
NEMA Standard 11-15-1991.

4.6.2 Welding Terminals

Terminals of the power source provided for the connection of welding leads shall be constructed to withstand an external pull, exerted for 1 minute from any direction, as specified in Table 4-3, without reducing the electrical spacings below those specified in Table 4-5 or without permanently deforming the terminals or adjacent parts. However, the pull applied to the welding terminals need not be more than that specified for the flexible cord used for the power supply connection. In the case of a jack plug, the plug can pull free of its jack with the application of a lesser pull.

Threaded connections used for the connection of welding leads shall withstand a torque as given by the following equation without reducing internal spacings below those given in Table 4-5 or without permanently deforming the terminals or adjacent parts:

$$T = 100 \times D^2 \text{ (customary units)}$$

$$T = 0.0175 \times D^2 \text{ (SI units)}$$

Where:
T = Torque in lb.-ft. (n.m).
D = Thread major diameter in inches (mm).

The welding terminals shall not exceed 60°C temperature rise when the power source is operated at rated-load current and duty cycle. When temperature testing, the welding leads connected to the welding terminals shall be in accordance with 4.6.1. Threaded connections used to hold the welding leads shall be tightened to a minimum torque as given in the following equation:

$$T = 60 \times D^2 \text{ (customary units)}$$

$$T = 0.0175 \times D^2 \text{ (SI units)}$$

NEMA Standard 1-11-1983.

4.7 INTERNAL WIRING REQUIREMENTS

4.7.1 Insulated Conductors

When internal wiring consists of insulated conductors, they shall be selected for the particular application with respect to the temperature, current, voltage, exposure to oil or grease, and other conditions of service to which they are likely to be subjected.

The wiring shall be so arranged or protected that no damage to the conductor insulation will occur from contact with any rough, sharp, or moving part.

All joints and connections shall be mechanically secured and shall provide electrical contact without mechanical strain on the conductor.

NEMA Standard 1-11-1983.

4.7.2 Uninsulated Conductors

When uninsulated conductors are used within an enclosure, they shall be so supported that the spacings given in Table 4-5 shall be maintained.

NEMA Standard 1-11-1983.

4.7.3 Insulating of Live Parts

Insulating washers, bushings, sheets, and such for the mounting of or insulation of live parts shall not be functionally damaged by the temperature to which they will be subjected during operation at rated load under usual service conditions.

NEMA Standard 1-11-1983.

4.8 SPACINGS

The minimum spacing between any uninsulated live part and another live, grounded, or isolated conductive part shall not be less than those shown in Table 4-5.

NEMA Standard 1-11-1983.

4.9 CLASSIFICATION OF INSULATION SYSTEMS

An insulation system is an assembly of insulating materials in association with the conductors and the supporting structural parts of an arc welding power source. Insulation systems are divided into classes according to the thermal endurance of the system for temperature rating purposes.

Insulation systems shall be classified as Class 105, Class 130, Class 155, Class 180, Class 200, or Class 220. Each insulation system is one that by experience or accepted test can be shown to have suitable thermal endurance when operating at the limiting temperature specified in temperature rise Tables 5-7 and 5-8.

The term "experience," as used in this paragraph, means successful operation for a long time under actual operating conditions of power sources designed with a temperature rise at or near the temperature rating limit.

The term "accepted test," as used in this paragraph, means a test on a system or model system that simulates the electrical, thermal, and mechanical stresses occurring in service.

Where appropriate to the construction, tests shall be made in accordance with the following applicable IEEE Test Procedures:

1. *Standard Test Procedure For Evaluation of Systems of Insulating Materials for Random-wound AC Electric Machinery*, IEEE Publication No. 117.
2. *Test Procedure Evaluation and Classification of Insulation System for DC Machines*, IEEE Publication No. 304.

For other constructions for which tests have not been standardized, similar procedures shall be permitted to be used if it is shown that they properly discriminate between service proven systems known to be different.

When evaluated by an accepted test, a new or modified insulation system shall be compared to an insulation system on which there has been substantial service experience.

If a comparison is made on a system of the same class, the new system shall have equal or longer thermal endurance under the same test conditions; if the comparison is made with a system of a lower temperature class, it shall have equal or longer thermal endurance at an appropriately higher temperature. When comparing systems of different classes, an appropriately higher temperature shall be considered to be 25°C per class higher than the temperature for the base insulation system class.

NEMA Standard 1-11-1983.

4.10 REQUIREMENTS FOR SPECIFIC COMPONENTS

4.10.1 Transformers

A power source transformer supplying welding current shall have the secondary winding(s) electrically isolated from the primary winding(s) when the power source is designed to be operated from power supply lines.

NEMA Standard 1-11-1983.

4.10.2 Capacitors

A capacitor, provided as part of a power source and connected across the power supply lines or a winding of the transformer providing welding current, shall be: (a) housed within the power source enclosure, or (b) housed in an enclosure or container that meets all of the applicable provisions of this standard. If a capacitor contains an insulating liquid, its container shall not leak under usual service conditions. If the liquid is flammable, the quantity shall be limited to 1 quart and the capacitor shall be protected against rupture of its container.

A capacitor shall be provided with automatic discharging means capable of reducing the potential across the capacitor to 50 volts within the time necessary to gain access to any current carrying part not in the output circuit of the machine after disconnecting the machine. If the potential across the capacitor exists at the blade of a disconnected attachment plug, the time of access is considered to be 2 seconds.

NEMA Standard 1-11-1983.

4.10.3 Switches and Control Devices

A switch, contactor, controller, or circuit breaker used to energize the power source shall perform satisfactorily for 6000 cycles of operation at a rate of 6 cycles per minute with the device making and breaking the input current(s) at rated input voltages of the power source when operated at rated load current. If such a device is known by prior testing or documentation to be suitable for the application, it need not be retested. Opening of the primary supply interrupting device employed in an arc welding power source shall disconnect all ungrounded supply conductors. Means shall be provided to indicate if this interrupting device has been turned on or off.

Exception: Control transformers having isolated windings that provide operating voltage for the primary supply interrupting device are not covered by this paragraph.

NEMA Standard 1-11-1983.

4.10.4 Operating Controls

A suitable means shall be provided for adjusting the output of an arc welding power source over the welding range specified by the manufacturer. Provision shall be made for indicating the approximate output setting(s) of the power source expressed as load voltage, load current, or by an arbitrary reference scale.

NEMA Standard 1-11-1983.

4.10.5 Marking of Connections and Operating Controls

All welding terminal connections, tap connections, and operating controls shall be plainly and permanently marked to designate their purpose and correct usage.

NEMA Standard 1-11-1983.

4.11 OUTPUT REGULATING TAPS

When load voltage or load current regulating tap switches are provided, they shall have established contact positions. Switches, brushes, or sliding type contacts shall not, if left between two contact positions, short circuit any winding turns unless tests show that such short circuiting will not cause temperature rises exceeding those specified in 5.9.

When load voltage or load current regulating taps involve the use of jack plugs and jacks, or equivalent means, external to the enclosure, the voltages at these locations shall not exceed those for welding terminals given in 5.3. Any flexible conductor used shall be suitable for welding service. Whatever means provided shall conform to the requirements of 3.1 regarding recessing or protection.

NEMA Standard 1-11-1983.

4.12 AUXILIARY POWER SUPPLY

4.12.1 Receptacles

A supply receptacle intended for providing power to 115 or 230 volt auxiliary equipment such as wire feeders, drills, grinders, and such, shall be of the grounding type, and the grounding contact of the receptacle shall be electrically connected to the enclosure of the power source. The current and voltage rating of the auxiliary power supply shall be marked at the receptacle location.

NEMA Standard 1-11-1983.

4.12.2 Protection

When supplied, a fuse(s) or circuit breaker(s) that protects the auxiliary power supply circuit shall be capable of interrupting the auxiliary power supply circuit. The current rating of a fuse shall be marked at the fuseholder location.

NEMA Standard 1-11-1983.

4.12.3 Auxiliary Power Supply Circuit

An auxiliary power supply circuit shall be electrically isolated from the input power supply.

NEMA Standard 1-11-1983.

4.13 SHORT CIRCUIT OF WELDING CIRCUIT

An arc welding power source shall not become a fire or shock hazard as a result of a short circuit of the welding circuit.

NEMA Standard 1-11-1983.

Protection of the power source against short circuit current may be accomplished by means of the branch circuit protection, provided at the time of installation, in accordance with Article 630 of the *1987 National Electrical Code,* official local codes and the manufacturer's recommendations.

Authorized Engineering Information 1-11-1983.

Section 5
RATING AND PERFORMANCE

5.1 INPUT RATING OF ARC WELDING POWER SOURCES OPERATING FROM ELECTRICAL POWER SUPPLIES

The preferred input voltages and frequencies shall be one or more of the following:

60 Hertz: 200, 230, 460 and 575 volts.
50 Hertz: 220, 380, and 415 volts.

The input current(s) of an arc welding power source operating from an electrical power supply shall be determined at the rated output when rated input voltage(s) and rated frequency(s) are applied.

For power sources with regulating taps, the input current(s) shall be determined under the conditions which result in the maximum input current when the output is the rated load current at the rated load voltage of the power source.

The actual input current(s) determined shall not vary from the input current(s) shown on the name plate by more than 10 percent for NEMA Class I and NEMA Class II power sources and 25 percent for NEMA Class III power sources.

NEMA Standard 1-11-1983.

5.2 POWER FACTOR CORRECTION

When power factor correction is provided, the corrected value shall be measured at rated load, rated input voltage(s) and frequency(s). The corrected value shall not be less than 75 percent unless the corrected value is specified on the nameplate.

NEMA Standard 11-17-1988.

5.3 OPEN CIRCUIT VOLTAGE

The open circuit voltage, excluding high frequency stabilization voltage, of an arc welding power source, using a voltmeter within the range of 100 ohms/volt and 1,000 ohms/volt, shall not exceed the following when rated input voltage is applied or when a generator type arc welding power source is operated at maximum rated no load speed:

5.3.1 Manual and Semiautomatic Arc Welding Power Sources

1. AC arc welding power source	80 volts rms*
2. DC arc welding power source with more than 10 percent ripple voltage (see 1.2)	80 volts rms
3. DC arc welding power source with 10 percent or less ripple voltage	100 volts average

*Because of the high ripple content, the average value reading may be in error, therefore, the rms value is used.

5.3.2 Automatic Arc Welding Power Sources

1. AC arc welding power source	100 volts rms
2. DC arc welding power source with more than 10 percent ripple voltage . . .	100 volts rms*
3. DC arc welding power source with 10 percent or less ripple voltage	100 volts average

NEMA Standard 11-17-1988.

5.4 OUTPUT RATINGS OF CONSTANT CURRENT NEMA CLASS I ARC WELDING POWER SOURCES

5.4.1 General

Constant current (see 1.2) NEMA Class I arc welding power sources having a duty cycle rating of 60, 80, or 100 percent shall have an output rating in load amperes and load volts in accordance with Column 1 of Tables 5-1 or 5-2. They shall be capable of providing the load amperes at the load volts for the minimum and maximum output settings associated with the rated load amperes and rated load volts given in Column 1 of Tables 5-1 and 5-2, see 5.4.2 and 5.4.3, when:

1. The welding terminals are connected to a resistance load having a power factor of 0.99 or higher.
2. A generator type power source is operated at rated load speed.
3. Rated input voltage at rated frequency is applied to the power source.
4. The temperature rise specified in 5.9 is not exceeded.

For an arc welding power source having dc output, the load amperes and load volts shall be expressed as average values. For an arc welding power source having an ac output, the load amperes and load volts shall be expressed as rms values.

NEMA Standard 1-11-1983.

5.4.2 AC or DC Arc Welding Power Sources

When the power source is operating at the maximum output setting shown in Column 3 of Table 5-1, the duty cycle shall not be less than one half the rated duty cycle of the power source.

NEMA Standard 1-11-1983.

Table 5-1
CONSTANT CURRENT, AC OR DC NEMA CLASS I ARC WELDING POWER SOURCES

Column 1		Column 2		Column 3	
Rated Output[a]		Minimum Output Setting[b]		Maximum Output Setting[c]	
Load Amperes at	Load Volts[d]	Load Amperes at	Load Volts[d]	Load Amperes at	Load Volts[d]
200	28	40	22	250	30
250	30	50	22	312	32
300	32	60	22	375	35
400	36	80	23	50	40
500	40	100	24	625	44
600	44	120	25	750	44
800	44	160	26	1000	44
1000	44	200	28	1250	44
1200	44	240	30	1500	44
1500	44	300	32	1875	44

Table 5-2
CONSTANT CURRENT, AC/DC NEMA CLASS I ARC WELDING POWER SOURCES

Column 1		Column 2		Column 3			
Rated Output(a)		Minimum Output Setting(b)		Maximum Output Setting(c)			
AC/DC		AC/DC		AC		DC	
Load Amperes at	Load Volts[d]	Load Amperes at	Load Volts[d]	Load Amperes at	Load Volts[d]	Load Amperes at	Load Volts[d]
200	28	40	22	250	30	200	28
250	30	50	22	312	32	250	30
300	32	60	22	375	35	300	32
400	36	80	23	500	40	400	36
500	40	100	24	625	44	500	40
600	44	120	25	750	44	600	44
800	44	160	26	1000	44	800	44
1000	44	200	28	1250	44	1000	44
1200	44	240	30	1500	44	1200	44
1500	44	300	32	1875	44	1500	44

[a] These tables list the preferred values of load ampere ratings. Other rated-load currents shall be permitted to be used as follows: For less than 250 amperes, the load current may be in steps of 25 amperes; for more than 250 amperes, the load current may be in steps of 50 amperes. In such cases, the values for the minimum output current shall be 20 percent of rated load current amperes and for maximum output shall be 125 percent of rated load amperes except that for power sources covered by Table 5-2, the DC maximum output current shall be 100 percent of rated load amperes. The load volts in each case shall be determined by the equation in note (d).

[b] Load amperes or load volts, or both, shall be permitted to be less than, but they shall not be more than, the values listed in the table.

[c] Load amperes or load volts, or both, shall be permitted to be more than, but they shall not be less than, the values listed in the table.

[d] These load voltages are based upon the equation $E = 20 + 0.04I$, where E is the load voltage and I is the load amperes. For load current larger than 600 amperes, the load voltage is 44 volts.

Table 5-3
CONSTANT CURRENT, AC OR DC NEMA CLASS II ARC WELDING POWER SOURCES

Column 1		Column 2		Column 3	
Rated Output[a]		Minimum Output Setting[b]		Maximum Output Setting[c]	
Load Amperes at	Load Volts[d]	Load Amperes at	Load Volts[d]	Load Amperes at	Load Volts[d]
150	26	30	21	165	27
175	27	35	21	193	28
200	28	40	22	220	29
225	29	45	22	248	30
250	30	50	22	275	31
300	32	60	22	330	33
350	34	70	23	385	36

5.4.3 AC/DC Arc Welding Power Sources

When the power source is operating at the maximum output setting shown in column 3 of Table 5-2, the duty cycle for the dc output shall be the rated duty cycle of the power source and the duty cycle for the ac output shall not be less than one half the rated duty cycle of the power source.

NEMA Standard 1-11-1983.

5.5 OUTPUT RATINGS OF CONSTANT CURRENT NEMA CLASS II ARC WELDING POWER SOURCES

5.5.1 General

Constant current (See 1.2) NEMA Class II arc welding power sources having a duty cycle rating of 30, 40, or 50 percent shall have an output rating in load amperes and load volts in accordance with Column 1 of Tables 5-3 or 5-4. They shall be capable of providing the load amperes at the load volts for the minimum and maximum output settings associated with the rated load amperes and load volts given in Column 1 of Tables 5-3 or 5-4. See notes B and C of Table 5-4 when:

1. The welding terminals are connected to a resistance load having a power factor of 0.99 or higher;
2. A generator type power source is operated at rated load speed;
3. Rated input voltage at rated frequency is applied to the power source; and
4. The temperature rise specified in 5.9 is not exceeded.

For an arc welding power source having a dc output, the load amperes and load volts shall be expressed as average values. For an arc welding power source having an ac output, the load amperes and load volts shall be expressed as rms values.

5.5.2 AC or DC Arc Welding Power Sources

When the power source is operating at the maximum output setting shown in Column 3 of Table 5-3, the duty cycle shall be not less than one half the rated duty cycle of the power source.

5.5.3 AC/DC Arc Welding Power Sources

When the power source is operating at the maximum output setting shown in Column 3 of Table 5-4, the duty cycle for the dc output shall be the rated duty cycle of the power source and the duty cycle for the ac output shall be not less than one half the rated duty cycle of the power source.

NEMA Standard 1-11-1983.

5.6 OUTPUT RATINGS OF CONSTANT CURRENT NEMA CLASS III ARC WELDING POWER SOURCES

Constant current (see 1.2) NEMA Class III arc welding power sources having a duty cycle rating of 20 percent shall have an output rating in load amperes and load volts in accordance with Column 1 of Table 5-5. They shall be capable of providing the amperes at the minimum and maximum output settings associated with the rated load amperes and rated load volts given in Column 1 of Table 5-5 when:

1. The welding terminals are connected to a resistance load having a power factor of 0.99 or higher;
2. A generator type power source is operated at rated load speed;
3. Rated input voltage at rated frequency is applied to the power source; and
4. The temperature rise in 5.9 is not exceeded.

For an arc welding power source having a dc output, the load amperes and load volts shall be expressed as average values. For an arc welding power source having

Table 5-4
CONSTANT CURRENT, AC/DC NEMA CLASS II ARC WELDING POWER SOURCES

Column 1		Column 2		Column 3			
Rated Output(a)		Minimum Output Setting(b)		Maximum Output Setting(c)			
AC/DC		AC/DC		AC		DC	
Load Amperes at	Load Volts[d]	Load Amperes at	Load Volts[d]	Load Amperes at	Load Volts[d]	Load Amperes at	Load Volts[d]
150	26	30	21	165	27	150	26
175	27	35	21	193	28	175	27
200	28	40	22	220	29	200	28
225	29	45	22	248	30	225	29
250	30	50	22	275	31	250	30
300	32	60	22	330	33	300	32
350	34	70	23	385	36	350	34

[a]These tables list the preferred values of load ampere ratings. Other rated load currents shall be permitted to be used as follows: For less than 150 amperes, the load current may be in steps of 25 amperes; for more than 350 amperes, the load current may be in steps of 50 amperes. In such cases, the values for the minimum output current shall be 20% of rated load amperes and for Maximum output shall be 110% of rated load amperes except that for power sources covered by Table 5-4, the dc maximum output current shall be 100% of rated load amperes. The load volts in each case shall be determined by the equation in the above asterisk note.

[b]Load amperes or load volts, or both, shall be permitted to be less than but they shall not be more than the values listed in the table.

[c]Load amperes or load volts, or both, shall be permitted to be more than but they shall not be less than the values listed in the table.

[d]These load voltages are based upon the equation $E = 20 + 0.04I$, where E is the load voltage and I is the load amperes.

Table 5-5
CONSTANT CURRENT, NEMA CLASS III ARC WELDING POWER SOURCES

Column 1		Column 2		Column 3
Rated Output[c]		Minimum Output Setting[d]		Maximum Output Setting[c]
Load Amperes at	Load Volts	Load Amperes at	Load Volts	
180 through 230[a]	25	Multiply rated load amperes by 1/6[b]	20	Same as rated output given in Column 1
235 through 295[a]	30	Multiply rated load amperes by 1/6[b]	22	Same as rated output given in Column 1

[a] Expressed in multiples of 5.

[b] If the number is not a multiple of 5, raise the number to the next multiple of 5.

[c] The measured load amperes at rated load volts shall be not less than 95 percent of the rated load amperes shown on the nameplate.

[d] Load amperes, load volts or both, shall be permitted to be less than, but they shall not be more than, the values listed in the table.

an ac output, the load amperes and load volts shall be expressed as rms values.

For arc welding power sources having an ac output only or a dc output only, the values given in Table 5-5 apply. For arc welding power sources having an ac/dc output, the values given in Table 5-5 apply for the ac output; the dc output shall be not less than 80 percent of the ac output set forth in Column 1 of Table 5-5, while the values in Column 2 of Table 5-5 apply directly to the dc output.

NEMA Standard 1-11-1983.

5.7 OUTPUT RATINGS OF CONSTANT VOLTAGE, NEMA CLASS I ARC WELDING POWER SOURCES

Constant voltage (see 1.2) NEMA Class I (see 1.2) arc welding power sources having a duty cycle rating of 60, 80, or 100 percent shall have an output rating in load amperes and load volts in accordance with Table 5-6 when:

1. The welding terminals are connected to a resistance load having a power factor of 0.99 or higher;
2. A generator type power source is operated at rated load speed;
3. Rated-input voltage at rated frequency is applied to the power source;
4. The temperature rise in 5.9 is not exceeded.

For an arc welding power source having a dc output, the load amperes and load volts shall be expressed as average values. For an arc welding power source having an ac output, the load amperes and load volts shall be expressed as rms values.

NEMA Standard 1-11-1983.

5.8 NO LOAD OPERATION

Arc welding power sources shall be capable of operating continuously at no load at any output setting without exceeding the temperature rises specified in 5.9.

NEMA Standard 1-11-1983.

5.9 TEMPERATURE RISE

When an arc welding power source, is operated at rated load speed or with rated input voltage at rated frequency applied, is connected to a resistance load (0.99 power factor or higher), and is operated:

Table 5-6
CONSTANT VOLTAGE, AC OR DC NEMA CLASS I ARC WELDING POWER SOURCES

Column 1		Column 2	
Rated Output (a)(b)		Minimum Output Setting (c)(d)	
Load Amperes at	Load Volts(e)	Load Amperes at	Load Volts(f)
200	28	50	14
250	30	62	15
300	32	75	15
400	36	100	16
500	40	125	17
600	44	180	19
800	44	240	22
1000	44	300	24
1200	44	360	24
1500	44	450	24

(a) Maximum amperes, maximum load volts, or both, shall be permitted to be more than the values listed in the table.

(b) This table lists the preferred values of load ampere ratings. Other rated load currents shall be permitted to be used as follows: for less than 500 amperes, the load current shall be permitted to be in steps of 25 amperes; for more than 500 amperes, the load current shall be permitted to be in steps of 50 amperes. For load volts see note (e). For minimum load current and voltage see note (d).

(c) Load amperes, load volts, or both, shall be permitted to be less than, but they shall not be more than, the values listed in the table.

(d) For the load currents described in note (b), the minimum output current shall be 25 percent of the rated load current for power sources rated 550 amperes and less and 30 percent of rated load current for power sources rated more than 550 amperes. For minimum load volts, see note (f).

(e) Load voltages are based upon the equation $E = 20 + 0.04I$ where E is the load voltage and I is the load current, but in no case shall exceed 44 volts.

(f) Load voltages are based upon the equation $E = 20 + 0.04I$ where E is the load voltage and I is the load current, but in no case shall exceed 24 volts.

a. At rated load current(s) and load voltage(s) (See 6.1) at rated duty cycle and;
b. At the maximum output setting(s) at the specified duty cycle until constant temperatures are attained, the temperature rise of the various parts shall not exceed the values given in Tables 5-7 and 5-8. Auxiliary power supplies intended to be used while welding shall be loaded to their rating.

In the case of power sources with output regulating taps in either the input circuit, the output circuit, or both, the temperature shall be measured with tap selections that will produce the highest temperatures at rated output or below.

NEMA Standard 1-11-1983.

5.10 NAMEPLATE MARKING

The following minimum information, where applicable, shall be given on the nameplate(s) of an arc welding power source.

1. Manufacturer's type designation and/or identification number;
2. "NEMA EW 1";
3. Maximum open circuit voltage (see 5.3);
   When a power source has an open circuit voltage in accordance with 5.3.2, a cautionary statement shall be provided indicating that the power source is not intended for manual or semiautomatic arc welding.
4. Rated load volts;
5. Rated load amperes;
6. Duty cycle at rated load;
7. Maximum rated speed of generator in rpm at no load;
8. Rated frequency(s) of power supply;
9. Number of phases of power supply;
10. Rated input voltage(s) of power supply;

Table 5-7
MAXIMUM TEMPERATURE RISE FOR DC GENERATOR, AC GENERATOR-RECTIFIER AND AC GENERATOR ARC WELDING POWER SOURCES

	Temperature Rise							
	DC Prime Mover Motors, DC Generators and Exciters				AC Generators, AC Generator-Rectifiers and Prime Mover Motors			
	Class of Insulation Systems				Class of Insulation Systems			
	105	130	155	180	105	130	155	180
1. Armature windings, multilayer field windings, and all windings other than those covered in item 2[a]								
By thermometer method[b]	50°C	70°C	90°C	110°C	–	–	–	–
By resistance method	60°C	85°C	110°C	135°C	60°C	85°C	110°C	135°C
2. Single layer windings consisting of exposed uninsulated or film-coated conductors[a]								
By thermometer method[b]	60°C	85°C	105°C	130°C	–	–	–	–
By resistance method	65°C	90°C	115°C	140°C	–	–	–	–
3. Cores and mechanical parts in contact or adjacent to insulation – by thermometer method[b]	50°C	70°C	90°C	110°C	50°C	70°C	90°C	110°C
4. Commutators – by thermometer method[b]	65°C	85°C	85°C	85°C	–	–	–	–

5. All parts other than those whose temperatures affect the temperature of the insulating material shall be permitted to attain such temperatures as will not injure the power source of its component parts in any respect.

6. Squirrel cage rotors shall not attain such temperatures as will cause mechanical injury to the power source.

7. For the temperatures of welding leads and welding terminals, see 4.6.

[a] Where two methods of temperature measurement are listed, a temperature rise within the values listed in Table 5-7, measured by either method, demonstrates conformity with this standard.

[b] A thermocouple shall be permitted to be substituted for a thermometer where applicable. For test procedures, see Section 6. For the description of classes of insulation systems, see 4.9.

11. RMS value(s) of the input current(s) amperes at rated load output (see 5.1);
12. Prime mover speed in rpm at no load if different from 5.10.7; and,
13. Power factor value as required in 5.2.

NEMA Standard 11-17-1988.

Table 5-8
MAXIMUM TEMPERATURE RISE FOR AC TRANSFORMER, DC TRANSFORMER-RECTIFIER AND AC OR DC TRANSFORMER-RECTIFIER ARC WELDING POWER SOURCES

Method of Temperature Determination[a]	Temperature Rise — Class of Insulation System					
	105	130	155	180	200	220
Resistance	70°C	90°C	115°C	135°C	155°C	170°C
Applied Thermocouple	80°C	100°C	125°C	150°C	170°C	190°C

Metallic parts in contact with any kind of insulation shall not attain a temperature in excess of that allowed for the adjacent insulation.

For the temperatures of welding leads and welding terminals, see 4.6.

All parts other than those whose temperatures affect the temperature of the insulating material shall be permitted to attain such temperatures as will not injure the power source, or its component parts, in any respect.

[a] A temperature rise within the values listed in Table 5-8, measured by either method, demonstrates conformity with this standard. For coils, transformer windings, and reactors, the resistance method of temperature determination is preferred.

For the description of classes of insulation systems, see 4.9.

For test procedures, see Section 6.

Section 6
TEMPERATURE TESTS

6.1 TESTING PROCEDURES FOR ARC WELDING POWER SOURCES

When power sources are tested for temperature rise in accordance with 5.9, the load current and load voltage shall be simultaneously maintained except that in the case of NEMA Class III power sources, the load voltage need not be maintained. The load voltage shall be measured at the welding terminals of the arc welding power source.

For arc welding sources having a duty cycle rating less than 100 percent, the test shall be conducted by starting and stopping the welding circuit in the manner in which the power source is designed to be used. All temperatures shall be measured at the end of the load time of the last cycle after constant temperatures are attained.

NEMA Standard 11-17-1988.

6.2 THERMOMETER METHOD OF TEMPERATURE DETERMINATION

6.2.1 Definition

The thermometer method consists of determining temperature by mercury or spirit thermometers or other suitable temperature measuring instruments* that shall be applied to the hottest parts accessible to ordinary mercury thermometers without alteration of the structure.

NEMA Standard 1-11-1983.

*When the thermometer method of temperature determination is called for, it is intended that the temperature measuring instrument used shall indicate substantially the same temperature as would be obtained by a liquid in glass thermometer in the same location.

6.2.2 Measurement

When temperature measurements of motor generator and engine generator arc welding power sources are made by the thermometer method, the tests shall be made, except as indicated in 6.1, 6.8, and 6.9, in accordance with the latest revision of the following applicable test codes:

1. *Test Procedure for Polyphase Induction Motors and Generators,* IEEE Publication No. 112.
2. *Guide on Test Procedures for DC Machines,* IEEE Publication No. 113.

NEMA Standard 11-17-1988.

6.3 RESISTANCE METHOD OF TEMPERATURE DETERMINATION

6.3.1 Definition

The resistance method consists of determining temperature by comparison of the resistance of a winding at the temperature to be determined with the resistance at a known temperature.

NEMA Standard 1-11-1983.

6.3.2 Measurement

When temperature measurements of arc welding power sources are made by the resistance method, the tests shall be made, except as indicated in 6.1, 6.8, and 6.9, in accordance with the following applicable test codes:

1. *Test Procedure for Polyphase Induction Motors and Generators,* IEEE Publication No. 112.
2. *Distribution Power, and Regulating Transformers, Test Code for Liquid Immersed,* ANSI/IEEE Publication No. C57.12.90.

6.3.3 Determination of Average Measured Temperature by the Resistance Method

The average measured temperature of either a copper or aluminum winding shall be determined by the following equation:

$$t_h = \frac{R_h}{R_c}(K + t_c) - K$$

Where:

t_h = temperature of winding in degrees celsius when R_h was measured

t_c = temperature of winding in degrees celsius when R_c was measured

R_h = hot resistance, ohms

R_c = cold resistance, ohms

K = for copper = 234.5
for aluminum = 225

NEMA Standard 1-11-1983.

6.4 APPLIED THERMOCOUPLE METHOD OF TEMPERATURE DETERMINATION

6.4.1 Definition

The applied thermocouple method consists of determining temperature by thermocouples or other suitable temperature measuring instruments of comparable size applied to the hottest parts accessible to thermocouples in locations that are normally inaccessible to liquid in glass thermometers.

NEMA Standard 1-11-1983.

Depending upon the thickness of the insulation separating them from current carrying conductors, thermocouples may give readings comparable to those obtained by the resistance method or may give the considerably lower readings characteristic of the thermometer method. Accordingly, in the measurement of winding temperatures by the use of thermocouples, the method will be defined as the "applied thermocouple method" only if the thermocouples are applied directly to the conductors or are separated from the metallic circuit only by the integrally applied insulation of the conductor itself.

Authorized Engineering Information 1-11-1983.

6.4.2 Measurement

When temperature measurements of arc welding power sources are made by the applied thermocouple method, the tests shall be made, except as indicated in 6.1, 6.8, and 6.9, in accordance with ANSI/IEEE Publication No. C57.12.90.

NEMA Standard 1-11-1983.

6.5 DETERMINATION OF AMBIENT TEMPERATURE

When temperature measurements are made, the ambient temperature shall be determined by at least three thermocouples, or thermometers, spaced uniformly around the arc welding power source under test. They shall be located at approximately one half the height of the power source and at a distance of 3 to 6 feet (1 to 2 meters) from the power source and shall be protected from drafts and abnormal heating.

NEMA Standard 1-11-1983.

6.6 COOLING AIR TEMPERATURE DURING TESTS

Temperature tests shall be made at any cooling air temperature, preferably not below 10°C. It shall be assumed that the temperature rise is the same for all cooling air temperatures between the limits of 10°C and 40°C.

NEMA Standard 1-11-1983.

6.7 OMISSION OF TEMPERATURE TEST ON DUPLICATE APPARATUS

A temperature test shall not be required when a record of test made on a duplicate unit in accordance with these standards can be furnished.

NEMA Standard 2-3-1936.

6.8 CORRECTION OF TEMPERATURE TO TIME OF SHUTDOWN

Whenever a sufficient time has elapsed between the instant of shutdown and the time of final temperature measurement to permit the temperature to fall, suitable corrections shall be applied so as to obtain as nearly as practicable the temperature at the instant of shutdown. One acceptable method to determine approximate temperature at the instant of shutdown is by plotting a curve, with temperature readings as ordinate and time as abscissa, and extrapolating back to the instant of shutdown.

In cases where successive measurements show increasing temperatures after shutdown, the highest value shall be taken.

NEMA Standard 1-11-83.

6.9 STOPPING GENERATOR-TYPE POWER SOURCES FOR TEMPERATURE TESTS

Precautions shall be taken to shorten the stopping period of generator-type arc welding power sources and to maintain the temperature during the stopping period. It is recommended that means be used to limit the stopping and measuring period to a value not exceeding that specified for the given rating as follows: (This sentence has been approved as Authorized Engineering Information.)

Up to and including 50 kilowatts—3 minutes

Above 50 kilowatts and including 200 kilowatts—5 minutes

NEMA Standard 11-17-1988.

Section 7
HIGH POTENTIAL TESTS

7.1 HIGH POTENTIAL TESTS

At the time of manufacture, each new and completely assembled arc welding power source shall be capable of passing the high potential test described in this Section.

NEMA Standard 1-11-1983.

7.2 TEST VOLTAGE

The ac rms test voltage for all arc welding power sources shall be 1000 volts plus twice the rated voltage of the circuit under test except for the alternative voltages specified for production line testing in 7.7. The frequency of all test voltages shall be 50 to 60 hertz, and the wave shape shall be essentially sinusoidal.

Repeated application of the high potential test voltage is not recommended. (This sentence is approved as Authorized Engineering Information.) If it becomes necessary to subject the arc welding power source to a subsequent high potential test, the test voltage shall be 85 percent of the appropriate test voltage applicable to the circuit under test.

NEMA Standard 1-11-1983.

7.3 DURATION OF APPLICATION OF TEST VOLTAGE

The test voltage for arc welding power sources shall be applied continuously for a period of 1 minute except for the alternative time periods specified for production line testing.

NEMA Standard 1-11-1983.

7.4 POINTS OF APPLICATION OF TEST VOLTAGE

Except for the production line testing specified in 7.7.2, the test voltage shall be successively applied between the input circuit of the arc welding power source and the metal frame and case; between the output circuit and the metal frame and case; and between other circuits such as control or auxiliary circuits and the metallic frame and case. All windings and circuits not under test and the core and other noncurrent carrying parts shall be connected to the metallic frame and case. Any electrical circuit that is isolated from the high potential test voltage by a switch, relay, or contactor shall be tested separately, or the switch, relay, or contactor shall be closed.

Alternatively, all circuits shall be tested by successively applying the test voltage directly between any two circuits and between any circuit and the metallic frame and case.

For purposes of high potential testing, an electric circuit consists of all windings and other live parts that are conductively connected to each power input terminal, to each output terminal of the welding power source, or to each terminal of any auxiliary or control receptacle or terminal. See 7.6.

NEMA Standard 1-11-1983.

7.5 TEMPERATURE AT WHICH HIGH POTENTIAL TESTS ARE TO BE MADE

High potential tests shall be made at room temperature or at any higher temperature attained during testing up to rated load operating temperature of the arc welding power source.

NEMA Standard 1-11-1983.

7.6 HIGH POTENTIAL TEST PROCEDURE FOR COMPONENTS AND ACCESSORIES

Except for the production line testing specified in 7.7.2, devices that do not fall within the scope of this publication but for which there are standards for high potential tests, such as meters, rectifiers, capacitors, lamp holders, switches, fractional horsepower motors, electronic equipment, ground detectors, etc., and that require lower test voltages than those called for in this publication, shall be grounded, short circuited or disconnected before the high potential tests are made on the arc welding power source.

NEMA Standard 1-11-1983.

7.7 PRODUCTION LINE HIGH POTENTIAL TESTING

One of the two tests specified in 7.7.1 and 7.7.2 shall be used in production line testing as an alternative to the 1 minute high potential test specified in 7.2, 7.3, and 7.4.

7.7.1 Arc welding power sources for which the test voltage is 2,500 volts or less shall be tested in accordance with 7.2 through 7.6 except that the test voltage shall be 1.2 times the one minute test voltage and the test time reduced to one second.

7.7.2 For this alternative test all of the following tests shall be made:

1. Prior to final assembly in the power source, components such as transformers, reactors (including saturable), magnetic amplifiers, motors, rectifier assemblies, and any other devices that are intended to be electrically connected to the input power supply manufactured inhouse shall be tested in accordance with 7.2 and 7.3. Application of the test voltage to such a device shall be be-

tween its input connected parts and its metal frame or mounting bracket parts.

2. Internally connected circuits that are not accessible during usual operation need not be tested; however, if such circuits derive their power from transformers connected to the input power supply, these transformers shall be tested in accordance with 7.7.2.1.

3. The completely assembled power source shall be tested at 1000 volts for 1 minute or 1200 volts for 1 second in accordance with 7.2 through 7.5.

NEMA Standard 1-11-1983.

During the test, circuitry employing solid state components or other electronic circuits may be electrically bypassed or disconnected to minimize the likelihood of damage to these components.

Authorized Engineering Information 1-11-1983.

Section 8
EFFICIENCY AND POWER FACTOR

8.1 METHOD OF DETERMINING EFFICIENCY AND POWER FACTOR

8.1.1 Conditions for Test

1. *Input*

The efficiency and input power factor of an arc welding power source shall be determined at rated input voltage, at rated frequency, and at measured input current.

2. *Output*

Efficiency and input power factor shall be determined at rated output when the power source is connected to a resistance load having a power factor of 0.99 or higher.

3. *Temperature*

The efficiency and input power factor shall be measured just prior to the conclusion of the temperature test.

4. *Miscellaneous Losses*

The power consumed by resistors, reactors, stabilizers, ventilating blowers, field and control rheostats, and other components, including separately excited fields and control windings, performing an essential function in the operation of the arc welding power source and included as an integral part of the power source shall be included in the determination of the efficiency and input power factor.

NEMA Standard 1-11-1983.

8.1.2 Efficiency

The efficiency of an arc welding power source shall be determined from simultaneous measurements of input power and output power.

NEMA Standard 1-11-1983.

8.1.3 Input Power Factor

The input power factor of an arc welding power source shall be determined from simultaneous measurements of input current, rated input voltage, and watts. Alternatively, a power factor meter shall be used.

NEMA Standard 1-11-1983.

Section 9
POWER SOURCES TO BE USED WITH GAS TUNGSTEN ARC WELDING

9.1 GENERAL

Special consideration shall be given when an arc welding power source is rated for use with the gas tungsten, arc welding process.

The provisions of this section shall be in addition to and not in place of the provisions of Sections 1 through 8 and Section 10, except as noted herein.

NEMA Standard 9-15-1983.

9.2 DEFINITIONS

9.2.1 Gas Tungsten Arc Welding (GTAW)

An arc welding process that produces coalescence of metals by heating them with an arc between a tungsten (nonconsumable) electrode and the work. Shielding is obtained from a gas or gas mixture. Pressure may or may not be used and filler metal may or may not be used.

Authorized Engineering Information 9-15-1983.

9.2.2 Shielding Gas

Shielding gas is a protective gas used to prevent atmospheric contamination of the weld.

NEMA Standard 9-15-1983.

9.3 VOLT AMPERE RELATIONSHIP FOR GTAW

For the purposes of this section, the relationship between output voltage (E) and output current (I) shall be given by the equation:

$$E(GTAW) = 13 + 0.12I$$

NEMA Standard 9-15-1983.

9.4 CATEGORIES OF GTAW POWER SOURCES

9.4.1 GTAW power sources shall be categorized by one of the following:

a. DC
b. AC
c. AC/DC

NEMA Standard 9-15-1983.

In some cases, power sources conforming to these standards may be equipped to produce pulsed current output. When providing pulsed current output, the power source rating may be affected and the manufacturers recommendations should be consulted.

Authorized Engineering Information 9-15-1983.

9.4.2 DC Power Sources

The rating and performance for a GTAW dc power source shall be determined in accordance with Section 5. *EXCEPTION:* Control transformers having isolated windings that provide operating voltage for the primary supply interrupting device are not covered by this paragraph.

When the minimum load current, welding current ranges, and dial calibration currents are given for GTAW, the load current/load voltage relationship shall be in accordance with the equation given in 9.3.

NEMA Standard 11-17-1988.

9.4.3 AC Power Sources

The rating and performance for a GTAW ac power source shall be determined in accordance with EW1, Part 5 except as follows:

a. The maximum and rated output values that are specifically for GTAW values shall be determined in accordance with the equation given in 9.3.
b. The welding terminals are connected to a resistance load having power factor of 0.99 or higher. Additionally, the load shall have a partial rectifying characteristic such that when the electrode terminal is negative with respect to the work terminal, the half cycle voltage shall be 16 volts plus or minus 0.5 volts less than the voltage when the electrode terminal is positive.

NEMA Standard 9-15-1983.

When the minimum load current, welding current ranges, and dial calibration currents are given for GTAW, the load current/load voltage relationship shall be in accordance with the equation given in 9.3.

NEMA Standard 9-15-1983.

Difference in emission characteristics between the electrode and the work may cause a voltage unbalance to occur across the arc. The voltage required to cause electron flow from the electrode to the work is less than the voltage required to cause electron flow from the work to the electrode. Unless means are incorporated to prevent it, this unbalance of voltage will cause current unbalance called a dc component. The dc component current may have an adverse effect on the operation and ratings of an ac arc welding power source.

AC GTAW should be carried out only on power sources specifically designed or recommended by the manufacturer for this purpose.

Authorized Engineering Information 9-15-1983.

9.4.4 AC/DC Power Sources

AC/DC GTAW power sources shall conform to 9.4.2 when furnishing dc to a load and 9.4.3 when furnishing ac to a load.

NEMA Standard 9-15-1983.

9.5 NAMEPLATE MARKING

Power sources specified for use on ac GTAW shall require nameplate markings of reduced duty cycle and output current rating in addition to those given in 5.10, unless the power source has the same output ratings as for dc GTAW. The appropriate additional nameplate markings shall be:

1. "GTAW (rated load amperes)"; or,
2. "GTAW (duty cycle at rated load)."

NEMA Standard 9-15-1983.

Section 10
ARC WELDING POWER SOURCES WITH HIGH FREQUENCY ARC STARTING AND/OR STABILIZING

10.1 GENERAL

The maximum open circuit voltage (OCV) given in 5.3 may not be sufficient for certain welding processes. A higher voltage may be required to maintain a stable arc, which is especially true for the ac GTAW welding processes.

Many processes use open circuit voltages sufficient to spark from the electrode to the work without making an intimate contact. In processes like the GTAW process, it may take several thousand volts to cause an electrical spark to jump this gap between the electrode and the work creating an initial path of ionization that the arc current can follow. In the submerged arc welding process, granules of flux often get between the electrode and the work piece making starting of the arc difficult at normal open circuit voltage.

Thus arc stabilizing and starting may require open circuit voltages greater than the maximum values of 5.3. In order to provide these higher voltages, it is common practice to superimpose a high open circuit voltage on the output of welding power sources by using high frequency techniques. The high frequency voltage is considered to be safer than the same voltage at line frequency or dc.

Authorized Engineering Information 9-15-1983.

10.2 DEFINITIONS

10.2.1 Conduction

Conduction is the transmission of HF energy via an electrical conductor or conducting medium. Examples would be wires, pipes, conduits, telephone lines, building beams, guy wires, reinforcement rods, conducting liquids, and such.

NEMA Standard 9-15-1983.

10.2.2 High Frequency (HF)

HF is radio frequency energy, either continuous or pulsed, used to start or stabilize a welding arc.

NEMA Standard 9-15-1983.

10.2.3 High Frequency Stabilized Arc Welding (HFSAW)

HFSAW is any of the arc welding processes utilizing HF.

NEMA Standard 9-15-1983.

10.2.4 Interference

Interference is the unwanted and problematic reception of HF energy.

NEMA Standard 9-15-1983.

10.2.5 Radiation

Radiation is the transmission of HF energy through space.

NEMA Standard 9-15-1983.

10.2.6 Welding Zone

The welding zone is the space within 50 feet (15 m) in all directions from the midpoint between the power source, and welding arc.

NEMA Standard 9-15-1983.

10.3 HF CLASSIFICATION

10.3.1 HF as an Integral Part (HFPS)

When the HF is supplied as an integral part of the power source, the manufacturer shall furnish operation and installation instructions as necessary to minimize radiation and thus minimize possible radio frequency interference.

NEMA Standard 9-15-1983.

10.3.2 HF Supplied as a Separate Unit (HFAU)

When HF units are supplied for attachment to power sources in general, the manufacturer of the HF unit shall supply operation and installation instructions as necessary to minimize radiation and thus minimize possible radio frequency interference, plus precautionary information regarding possible malfunctioning or overheating of the power source.

NEMA Standard 9-15-1983.

HF attachments are to be used only on those power sources specified by the power source manufacturer.

Authorized Engineering Information 9-15-1983.

10.3.3 Enclosure (HFPS or HFAU)

The enclosure of the HFPS or HFAU shall be metallic or metalized plastic of such nature as to provide a shield that can be grounded.

NEMA Standard 9-15-1983.

10.4 RADIO FREQUENCY RADIATION

10.4.1 General

Installations using HF either as an integral part of the power source or as an attachment unit will produce some high frequency radiation. Such radiation, if the signal strength is sufficient at the receiving device, can cause an inconvenience or disruption in communications or can cause malfunction in sensitive electronic controls and systems. To minimize these problems, radiation should be held to a minimum. This is best accomplished by following the manufacturer's operation and installation procedures.

Authorized Engineering Information 11-17-1988.

10.4.2 Direct Radiation from the Power Source or HF Attachment Unit (HFAU)

Direct radiation is that radiation emanating directly from the power source or attachment unit. Radiation from power line and welding circuit attachments is not considered to be direct radiation from the power source or attachment unit.

Authorized Engineering Information 11-17-1988.

10.4.3 Direct Radiation From the Welding Circuit

Any attachment to the output terminals of the high frequency source is capable of acting as an antenna and transmitting radiation. Attachments include leads, torches, worktables, and such, either necessary or unnecessary. Since direct radiation from the welding circuit is the major source of radiation, it is important to keep attachments to a minimum.

Authorized Engineering Information 11-17-1988.

10.4.4 Conduction and Radiation from the Power Line

Most power lines are capable of conducting high frequency energy which may cause interference directly or by radiation from these power lines. Most conducted power line radiation comes from direct radiation picked up by the power lines and reradiated. Normally such interference is small when compared to that caused by radiation from the welding leads.

Authorized Engineering Information 11-17-1988.

10.4.5 Reradiation

Radiation from the welding circuit can be picked up by ungrounded metal objects or unshielded wiring in the immediate vicinity, conducted some distance, and reradiated. This can be a troublesome source of interference.

Authorized Engineering Information 11-17-1988.

10.5 GENERAL PRINCIPLES FOR INSTALLATION OF HIGH FREQUENCY STABILIZED ARC WELDING INSTALLATIONS

10.5.1 Primary Power Supply

The HFAU or HFPS should be connected to the primary power supply in accordance with the manufacturer's instructions.

Unless the HFAU or HFPS is supplied with a flexible cord for connection to the primary power supply, the primary power supply conductors located within the welding zone should be completely enclosed in solid metallic conduit or in "equivalent shielding." Shielding should be electrically continuous throughout its length. The shielding is to be connected to the enclosure of the HFAU or HFPS so that good electrical contact is provided between the shielding and the enclosure.

When an HFAU or HFPS is furnished with an attached flexible power cord for connection to the primary power supply, additional shielding of this cord is not normally required. The primary power supply conductors should be shielded in accordance with the above paragraph up to the point of connection of the flexible power cord. The grounding conductor of the flexible cord should be used to provide a good electrical connection between the primary power supply conductor shielding and the HFPS welding enclosure. In case of an HFAU, it may be necessary to shield the existing flexible power cord connected to the power source or to replace it with primary supply conductors completely enclosed in solid metallic conduit or equivalent shielding. Consult manufacturer's instructions for both power source and HFAU installation.

Authorized Engineering Information 9-15-1983.

10.5.2 Access Doors and Covers

When the HFAU or HFPS is in operation, all access doors and covers should be closed and properly fastened. Except for those changes and adjustments covered in the manufacturer's instructions, units should not be altered in any way.

Authorized Engineering Information 9-15-1983.

10.5.3 Shielding of Miscellaneous Wiring in the Welding Zone

The connection of the ground to the shielding of the miscellaneous wiring in the welding zone should be at the closest proximity to the midpoint between the welding terminals and the arc. Conduit sections should be electrically bonded together.

Ungrounded metallic conductors in the welding zone can act as antennae that will pick up, conduct, and reradiate the HF energy transmitted by the welding circuit. Therefore, no unshielded miscellaneous conductors should be located within the welding zone. This means that all lighting, power, telephone, communication, and other conductors within the welding zone should be enclosed in welding grounded rigid metallic conduit, copper braid, or some other material having an equivalent shielding efficiency. Ordinary flexible helically wrapped metallic conduit is generally not suitable.

Authorized Engineering Information 11-17-1988.

10.5.4 Miscellaneous Conducting Materials in the Welding Zone

Miscellaneous conducting materials should not be located in the welding zone. Such materials that cannot be excluded should be grounded.

Authorized Engineering Information 1-11-1983.

10.5.5 Welding Circuit

The welding leads should be kept as short as possible and should not exceed 25 feet (7.6 m) in length. These leads should be positioned close together and should be kept as close to the ground or floor as possible. The use of unnecessary attachments, such as spare or auxiliary torches, electrode holders and such. in the welding circuit should not be allowed.

The magnitude of the HF energy transmitted as well as the frequency spectrum of such transmission may be altered substantially by changing the lengths or position of the welding leads.

Authorized Engineering Information 11-17-1988.

10.5.6 Grounding of the Welding Circuit

The most important ground connection is usually the one that is attached to the work terminal of an HFPS or the work connection of an HFAU. Therefore, unless otherwise specified by the manufacturer, the user should provide this ground connection according to ANSI Z49.1 as follows:

a. An impedance of not more than two ohms at the fundamental frequency and through the tenth harmonic of the fundamental frequency should be connected between the work terminal or connection and the enclosure of the HFAU or HFPS.
b. Further, the enclosure should be connected to a driven ground rod or to a metal water pipe either of which should enter the earth within 10 feet (3 m) of the power supply case.
c. All electrical connections should be made with clean bright metal surfaces.

Authorized Engineering Information 1-11-1983.

10.5.7 Metal Buildings

Locating an HFSAW installation within an electrically bonded and grounded metal building can be an effective means of reducing HF radiation. It is recommended that, wherever possible, HFSAW installations be made in such places.

Authorized Engineering Information 9-15-1983.

10.6 CERTIFICATION OF HFSAW INSTALLATIONS

10.6.1 Introduction

The *Code of Federal Regulations,* Title 47 "Telecommunications, " Part 18 requires all high frequency stabilized arc welding installations to have certification. Certification can be based on manufacturer's prototype tests when equipment is installed in accordance with the manufacturer's instructions, or by actual on-site measurements.

Authorized Engineering Information 9-15-1983.

10.6.2 On-site Certification

On-site testing for certification is the measurement of HF radiation as installed and operated on the user's premises. Users with a large number of machines may choose this method as the easiest and most expedient because there are no specific installation requirements other than those concerned with safe practices in the work place and any that might be necessary to obtain satisfactory measurements.

Procedures for certification based on-site measurements are given in FCC rules and regulations.

Authorized Engineering Information 9-15-1983.

10.6.3 Prototype Certification

As an alternative to on-site certification, prototype certification may be chosen. This means that certification of an installation is based on the manufacturer's prototype tests. To certify an installation by the prototype procedure, the manufacturer conducts tests described in 10.6.4. Based on these test results, the manufacturer provides instructions for the HFSAW installation and operation. When the HFSAW installation is as specified by the manufacturer and the equipment is being operated in accordance with the manufacturer's instructions, the user so stipulates by signing a certification form provided by the manufacturer. The term "user" means a person having overall responsibility for the installation and operation of the equipment. For example, this person may be a company officer, superintendent, or general foreman.

Authorized Engineering Information 9-15-1983.

10.6.4 Test Procedure for Prototype Certification

10.6.4.1 MEASUREMENT OF FIELD STRENGTH

Measurement to determine the field strength of HF radiation that is generated by a HFSAW installation shall be made in accordance with the *Code of Federal Regulations,* Title 47, Part 18* and American National Standard Institute (ANSI), *Methods of Measurement of Radio Emission from Low-Voltage Electrical and Electronic Equipment in the range of 10KHz to 1GHz,* ANSI Publication No. C63.4 utilizing the test setup described in 10.6.4.4.

NEMA Standard 9-15-1983.

*Office of Information and Regulatory Affairs, Management and Budget, Old Executive Office Building, Washington, D.C. 20503, 202-395-3000. Attention Deck Officer for Federal Communications Commission.

10.6.4.2 Measuring Instrument

Broad band emissions from the HFSAW installation shall be measured by an instrument having performance characteristics that are similar to those given in the American National Standard, *Standard or Instrumentation — Electromagnetic Noise and Field-Strength, 10KHz to 406Hz — Specification*, ANSI Publications No. C63.2.

Quasi-peak values of field strength shall be measured and used to determine the conformity with Part 18 of the Federal Communications Commission's Rules and Regulations.

A suitable loop antenna shall be used. The height of this antenna shall not exceed 12 feet (3.7 m) above the immediate terrain as measured to the center of the antenna.

NEMA Standard 9-15-1983.

Instruments that do not have the characteristics described in this Section may be used provided that a suitable correlation factor is used to adjust the field strength readings to values that would be obtained with an instrument having the specified characteristics. The derivation of this correlation factor may be explained in detail.

Authorized Engineering Information 9-15-1983.

10.6.4.3 Measuring Procedures

Measurement shall be made with the HFAU or HFPS "ON" while welding or while not welding, whichever condition yields the higher radiation. The "welding condition" means that the welding leads shall terminate in an actual arc or a load with a low HF impedance. The "not welding condition" means that the welding leads shall terminate in an open circuit. The presence of current other than that produced by the high frequency arc stabilizer is not required.

To determine the radiation attenuation with respect to distance, additional measurements shall be made at a minimum of 200 feet (60.1 m) increments in a straight radial line out to 1,000 feet (305 m) or to the measurement limits of the instrument, whichever comes first. These are made over the same frequency range and using the loop antenna procedure and midpoint as above. The fundamental and significant harmonic peaks shall be recorded. A control that affects the intensity of the high frequency shall be set for maximum intensity. Spark gaps and other internal adjustments shall be set in accordance with the manufacturer's instructions.

NEMA Standard 9-15-1983.

10.6.4.4 Manufacturer's Test Installation

1. Location
   Tests shall be made in a level open field which shall be as free as possible of wire fences and other metallic objects.
2. Ground Plane
   Measurements shall be made with the HFSW installation operated on a continuous metal ground plane. This ground plane shall be of at least 0.025 inch (0.64 mm) thick copper or of at least 0.040 inch (1.02 mm) thick aluminum. The ground plane shall be at least 36 inches (91.4 mm) in width. If the equipment to be tested exceeds 36 in. (91.4 mm) in width, then a ground plane of at least equal width shall be used. The ground plane shall be of at least sufficient length to extend from the outer edge of the work table to the rear of the power source.
   Minimum grounding for the ground plane shall be a copper clad steel rod at least 0.5 inch (12.7 mm) diameter located at the center of the ground plane width and at the rear of the power source. The rod shall be driven at least 8 feet (2.4 m) into the earth. The ground plane shall be bonded to this rod in accordance with good radio frequency bonding practice.
3. Work table
   The work table shall be of steel and shall have the following approximate dimensions:
   Length — 30 inches (762 mm)
   Width — 30 inches (762 mm)
   Height — 30 inches (762 mm)
   A clamp shall be provided to hold the electrode holder or torch in position on the work. All four legs of the work table shall be suitably bonded to the ground plane. If a low HF impedance load is used, it shall be placed as close as practical to the point that would normally be the welding arc.
4. The HF equipment shall be positioned over the ground plane but separated from it by approximately 0.75 inch (19.0 mm) of electrical insulating material. The work terminal and the enclosure(s) shall be bonded to the ground plane (see 10.5).
5. Power shall be furnished to the equipment as specified in the manufacturer's instructions. When power cords are furnished, they shall be used. Safety grounds as found in normal power service shall also be attached.
   Multiphase power sources shall be tested with power to all three phases or, alternately, with the power being supplied to the high frequency arc stabilizer only, provided that a low HF impedance load is used in accordance with 10.6.2.3.
6. The test setup is shown in Figure 10-1. The arc or load shall be located 25 feet (7.6 m) from the welding terminals of the HFPS or HFAU and shall be centered on the work table. Welding leads shall have an ampacity conforming to the rating of the

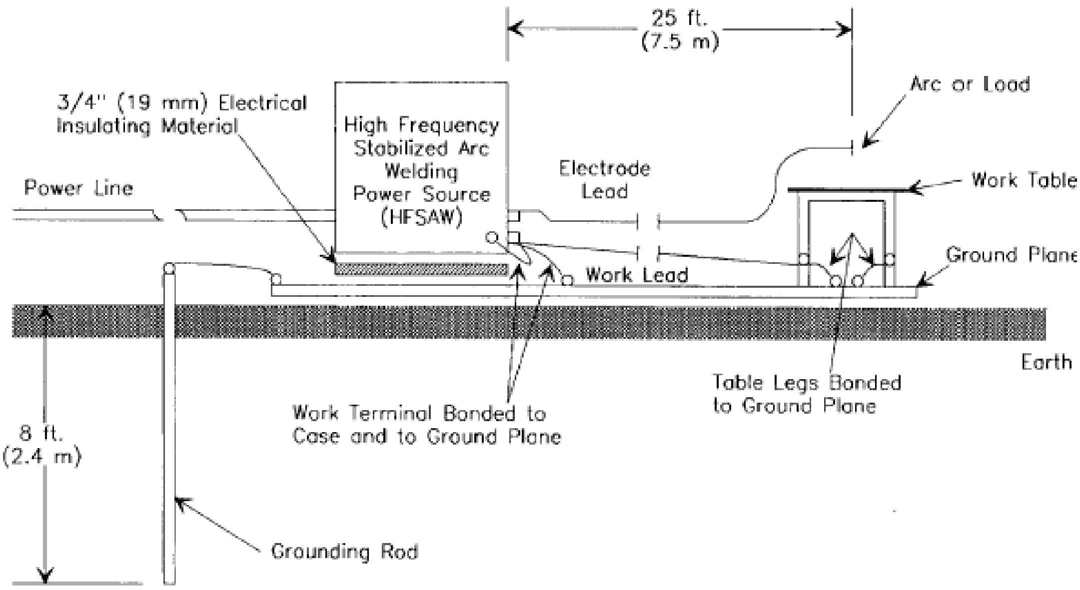

Figure 10-1
TEST SETUP

power source. They shall be as short as possible, positioned close together and lying on the ground plane.

NEMA Standard 9-15-1983.

10.6.5 Data Requirements and Limits

The data taken at 100 feet (30.5 m) shall be plotted or examined by any convenient or graphical method to determine the presence or absence of lobes. If the plot is basically circular—that is, not more than 6 db variation, then the radial measurement out to 1,000 feet (305 m) can be made in any convenient direction. If the 1,000 feet (305 m) radial series is taken where the variation is greater than 6 db from circular, the radial measurements must be made in the direction of the maximum lobe or the data corrected to correspond to a maximum lobe.

The 1,000 feet (305 m) radial data shall be examined and an extrapolation made either graphically or mathematically to determine the radiation level that would exist at one mile. The limit of radiation shall be a maximum of 10 microvolts per meter at 1 mile.

NEMA Standard 9-15-1983.

A convenient way to make this determination is to use linear by three cycle log paper. Plot the measured db on the linear axis and the distance on the log axis starting at cycle 2 as 100 feet (30.5 m).

Authorized Engineering Information 9-15-1983.

10.6.6 Interference

In the case of interference from an HF installation, it is the user's responsibility to confirm compliance with the *Code of Federal Regulations,* Title 47, Part 18 or to take such action as necessary to reduce or eliminate such interference to a point satisfactory to the parties involved.

Authorized Engineering Information 9-15-1983.

NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status, are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below.

Purpose of Standards

National Electrical Manufacturers Association standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist purchasers in selecting and obtaining the proper product for their particular needs. Existence of a National Electrical Manufacturers Association standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.
(Standardization Policies and Procedures, p. 1)

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process, or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.
(Standardization Policies and Procedures, p. 2)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the Standards Publication may be capable of otherwise equivalent performance.
(Standardization Policies and Procedures, p.8)

Categories of Standards

National Electrical Manufacturers Association Standards are of two classes:

1. NEMA Standard, which relates to a product, process, or procedure commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

(Standardization Policies and Procedures, pp. 7 & 16)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote on the standard.
(Standardization Policies and Procedures, pp. 7 & 16)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment, and/or approval, and which has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon.
(Standardization Policies and Procedures, pp. 7 & 16)

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

ARC WELDING SECTION
OF THE
NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

MEMBER COMPANIES

Alloy Rods Corporation
Hanover, PA 17331

Century Manufacturing Company
Minneapolis, MN 55431

C K Systematics, Inc.
Auburn, WA 98002

ESAB Welding Products, Inc.
Chicago, IL 60632

Hobart Brothers Company
Troy, OH 45373

Hypertherm, Incorporated
Hanover, NH 03755

The Lincoln Electric Company
Cleveland, OH 44117

L-TEC Welding & Cutting Systems
Florence, SC 29501

Miller Electric Mfg. Company
Appleton, WI 54912

National Standard Company
Niles, MI 49120

Pow Con Inc.
San Diego, CA 92126

Sandvik Steel Company
Welding and Wire Division
Scranton, PA 18501

Stoody Deloro Stellite, Inc.
St. Louis, MO 63105

Teledyne McKay
York, PA 17405-1509

Thermadyne Industries, Inc.
St. Louis, MO 63105

EW 3

SEMIAUTOMATIC WIRE FEED SYSTEMS FOR ARC WELDING

Revision No. 1—November 1991

Published by:

National Electrical Manufacturers Association
2101 L Street, N.W., Suite 300
Washington, D.C. 20037

NOTICE AND DISCLAIMER

TABLE OF CONTENTS

	FOREWORD	i
	SCOPE	ii
	PURPOSE	ii
Section 1	REFERENCED STANDARDS AND DEFINITIONS	
	Referenced Standards	1
	Definitions	2
Section 2	SERVICE CONDITIONS	
	General	4
	Usual Service Conditions	4
	Unusual Service Conditions	4
Section 3	MECHANICAL CONSTRUCTION REQUIREMENTS	
	Frames and Enclosures—General Strength Conditions	5
	Enclosure of Live Parts	5
	Openings in Enclosures	5
	Enclosure Construction	5
	Rotating Parts	6
	Filler Wire Supply	6
	Corrosion Protection	6
	Service Line Hoses	7
	Gun Assembly	7
	Water Cooling	7
	Drop Testing	7
Section 4	ELECTRICAL CONSTRUCTION REQUIREMENTS	
	Service Line Cords, Cables, and Connections	9
	Wire Feed Unit and Control	9
	Gun Assembly and Gun Cable Assembly	10
	High-Potential Test and Insulation Resistance	10
Section 5	RATING AND PERFORMANCE	
	Rating of Wire Feed System	12
	Performance	12
	Temperature Testing	12
	Other Performance Data	13
Section 6	MARKINGS	
	Wire Feeder Nameplate	14
	Gun Assembly and Gun Cable Assembly Nameplate	14
LIST OF TABLES		
	3-1 Thickness of Sheet Metal for Enclosures	7
	5-1 Maximum Temperatures of External Surfaces	12
LIST OF FIGURES		
	3-1 Probe	5
	3-2 Enclosure Opening	6
	3-3 Probe	6
	5-1 Part 1—Flux Cored Arc Welding without Gas	15
	5-1 Part 2—Flux Cored Arc Welding with CO_2 Gas	16

5-2 Part 1 – Gas Metal Arc Welding with CO_2 Gas and Solid Electrode 17
5-2 Part 2 – Gas Metal Arc Welding with Argon Gas and Solid Electrode 18
5-3 Gas Tungsten Arc Welding with Filler Wire 19

Foreword

This Standards Publication was developed by the NEMA Arc Welding Section and it includes requirements for construction, ratings, and performance applying to certain wire feed systems used in semiautomatic arc welding processes. These requirements are based upon sound engineering principles, research, and records of tests and field experience. Also involved is an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, and others having specialized experience.

Two 90-day public reviews for comments were solicited through the American Welding Society's *Welding Journal* and the NEMA Arc Welding Section canvass list in order to ensure that the views of interested parties in the public and private sector were given full consideration. Their comments and suggestions, prior to final NEMA approval, provided vital user and general interest input, and resulted in a number of substantive changes being made in this publication.

These standards will be reviewed periodically by the Arc Welding Section of NEMA for any changes which may be necessary to keep them up to date. As future major revisions to this publication are proposed, it is intended to offer the same or similar individuals a further opportunity to participate in the development of this publication. Proposed or recommended revisions should be submitted to:

Vice President, Engineering
National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, D.C. 20037

Scope

This Standards Publication applies to wire feed systems used in semiautomatic arc welding processes such as gas-metal arc welding, flux-cored arc welding with gas, flux-cored arc welding without gas, submerged arc welding, and gas-tungsten arc welding with the addition of filler wire.

The wire feed unit may be a stand-alone unit which may be connected to a separate arc welding power source or one where the arc welding power source and the wire feed unit are housed in a single enclosure. This publication does not apply to automatic arc welding systems or to gas-tungsten arc welding apparatus without the addition of filler wire.

Purpose

This NEMA Standards Publication is adopted in the public interest to provide a standard for performance and construction and in doing so to assist buyers in selecting and obtaining the proper product for their particular need.

Recommended safe practices and installation intended to prevent personal injury and property damage arising out of the use of this equipment are covered more completely in other related safety publications such as the manufacturers' instructions; ANSI/NFPA 70, *National Electrical Code*; ANSI/AWS Z49.1, *Safety in Welding and Cutting*; and AWS C5.6, *Recommended Safe Practices for Gas-Metal Arc Welding*.

Section 1
REFERENCED STANDARDS AND DEFINITIONS

1.1 REFERENCED STANDARDS

American National Standards Institute
1430 Broadway
New York, NY 10018

Z49.1-1988	*Safety in Welding and Cutting*
C57.12.90-1987	*American National Standard for Distribution Power, and Regulating Transformers Test Code for Liquid Immersed*
C63.2-1987	*Standard for Instrumentation - Electromagnetic Noise and Field Strength, 10KHz to 40GHz - Specific*
C63.4-1981	*Methods of Measurement of Radio Noise Emissions from Low-Voltage Electrical and Electromagnetic Equipment in the 10KHz to 1GHz Range.*

American Welding Society
550 N.W. LeJeune Road, P.O. Box 351040
Miami, FL 33135

C5.6-1979	*Recommended Practices for Gas-Metal Arc Welding*

Compressed Gas Association
Crystal Gateway 1, Suite 501
1235 Jefferson Davis Highway
Arlington, VA 22202

E-1-1980	*Standard Connections for Regulator Outlets, Torches and Fitted Hose for Welding and Cutting Equipment*
E-2-1983	*Hose Link Check Valve Standards for Welding and Cutting*

Institute of Electrical and Electronics Engineers
345 E. 47th St.
New York, NY 10017

112-1984	*Standard Test Procedure for Polyphase Induction Motors and Generators*
113-1985	*Guide on Test Procedures for DC Machines*
117-1974 (R1985)	*Standard Test Procedure for Evaluation of Systems of Insulating Materials for Random-Wound AC Electric Machinery*
304-1977	*Test Procedure Evaluation and Classification of Insulation System for DC Machines*

National Electrical Manufacturers Association
2101 L Street, N.W., Suite 300
Washington, D.C. 20037

WD 1-1983	*General Requirements for Wiring Devices*
EW 1-1988	*Electric Arc Welding Power Sources*

National Fire Protection Association
Batterymarch Park
Quincy, MA 02269

ANSI/NFPA 70-1990 — *National Electric Code*

Rubber Manufacturers Association
1400 K Street, N.W.
Washington, D.C. 20005

IP2-1987 — *Hose Handbook*

IP7-1990 — *Specifications for Rubber Welding Hose*

Underwriters Laboratories, Inc.
333 Pfingsten Road
Northbrook, IL 60062

ANSI/UL 94-1990 — *Test for Flammability of Plastic Materials for Parts in Devices and Appliances*

ANSI/UL 551-1986 — *TransformersType Arc Welding Machines*

1.2 DEFINITIONS

AUTOMATIC ARC WELDING

Welding with equipment which performs the entire welding operation without constant observation and adjustment of the controls by an operator. The equipment may or may not load and unload the work.

NEMA Standard 11-6-1975.

CONTACT TUBE

A device which transfers welding current to a continuous electrode.

NEMA Standard 11-6-1983.

DRIVE ROLLS

Rolls which contact the filler wire and transfer the mechanical power from the motor/gear portion of the wire-feed unit to the filler wire to feed the wire from the filler wire supply to the arc.

NEMA Standard 11-6-1975.

DUTY CYCLE

The ratio (expressed as a percent) of arc time to total time. For the purpose of these standards, the time period of one complete cycle shall be 10 minutes.

NEMA Standard 11-6-1975.

ELECTRODE

A component of the welding circuit in the form of continuous filler wire through which the welding current is conducted. It is melted by the arc and deposited in the weld seam.

NEMA Standard 11-6-1975.

FILLER METAL

The metal to be added in making a weld.

NEMA Standard 11-6-1975.

FILLER WIRE

Filler metal in wire form.

NEMA Standard 11-1-1983.

FILLER WIRE CONDUIT

A flexible, tubular member which insulates or guides the filler wire, or both.

NEMA Standard 11-6-1975.

FILLER WIRE SUPPLY

The filler wire which is stored for continuous pay-out to the wire feed unit. The wire feed unit may have integral provisions for the filler wire supply, or the filler wire supply may be remote from the wire feed unit with continuous pay-out achieved by means of filler wire conduit, pulleys, rollers, etc.

NEMA Standard 11-6-1975.

FLUX CORED ARC WELDING (FCAW)

An arc welding process wherein coalescence is produced by heating with an arc between a continuous filler metal (consumable) electrode and the work. Shielding is obtained from a flux contained within the tubular electrode. Additional shielding may or may not be obtained from an externally supplied gas or gas mixture.

NEMA Standard 1-11-1983.

GAS METAL ARC WELDING (GMAW)

An arc welding process which produces coalescence of metals by heating them with an arc between a continuous filler metal (consumable) electrode and the work. Shielding is obtained entirely from an externally supplied gas or gas mixture.

NEMA Standard 1-11-1983.

GAS TUNGSTEN ARC WELDING (GTAW).

An arc welding process that produces coalescence of metals by heating them with an arc between a tungsten electrode (non-consumable) and the workpieces. Shielding is obtained from a gas. Pressure shall be permitted to be used, and filler metal shall be permitted to be used.

NEMA Standard 11-17-1989.

GUN ASSEMBLY

A hand held manipulated device which guides the filler wire into the arc. It may include provisions for the transfer of welding current to the electrode, shielding, fume removal, filler wire supply, and control means for the welding process.

NEMA Standard 11-6-1975.

GUN CABLE ASSEMBLY

The flexible supply lines necessary for the operation of the gun assembly. It includes a cable which carries welding current and may also include a filler wire conduit, means for conveying shielding medium, cooling medium, means for fume removal, control wires, and line for nonelectric drives.

NEMA Standard 1-11-1983.

GUN SWITCH

The part of the gun assembly that is used to start, stop, or otherwise control the wire feed system.

NEMA Standard 11-6-1975.

INPUT CONTROL CURRENT

The input amperage required to operate the wire feed system.

NEMA Standard 11-17-1989.

INPUT CONTROL FREQUENCY

The nominal frequency or frequencies of the input control voltage.

NEMA Standard 1-11-1983.

INPUT CONTROL POWER

The input electrical power required to operate the wire feed system.

NEMA Standard 11-17-1989.

INPUT CONTROL VOLTAGE

The input voltage required from an external source to operate the wire feed system.

NEMA Standard 1-11-1983.

LIVE PARTS

Any parts which can be expected to be electrically energized during normal operation.

NEMA Standard 11-6-1975.

MANUFACTURER

The company whose name is shown on the nameplate.

NEMA Standard 11-6-1975.

MAXIMUM LOAD

The maximum mechanical load at the various rated wire feed speeds over the operating ranges of the equipment at which the wire feed unit and wire feed control can operate at the rated duty cycle without causing the rated temperature rise of any component to be exceeded.

NEMA Standard 11-6-1975.

NOZZLE

A device which directs shielding medium to or removes fumes from the welding arc.

NEMA Standard 1-11-1983.

RATED CURRENT

The amperage at which a device can operate at the rated duty cycle without exceeding its rated temperature.

NEMA Standard 11-17-1989.

RATED SPEED RANGE

The wire feed speed range in inches per minute or millimeters per second, or both, listed by the manufacturer for each rated size of filler wire.

NEMA Standard 11-6-1975.

SEMIAUTOMATIC ARC WELDING

Arc welding with equipment which controls only the feeding of the filler wire. The manipulation of the welding gun assembly is manually controlled.

NEMA Standard 11-6-1975.

SERVICE LINES

The lines between the source of power equipment or other equipment, or both, and the wire feed control or unit. These lines may consist of:

1. A welding cable to supply the welding power to the system.
2. Flexible cord(s) to supply input control power and to interconnect control circuits, such as that for the welding contractor, as required.
3. Hoses to supply shielding medium, cooling or fume removal.
4. Hoses, lines, or conduits required for nonelectric power or control.

NEMA Standard 1-11-1983.

SHIELDING MEDIUM

Gas, flux, or other material which is used to shield the arc and molten weld metals from the atmosphere.

NEMA Standard 1-11-1983.

SUBMERGED ARC WELDING (SAW)

An arc welding process which produces coalescence of metals by heating them with an arc or arcs between a bare metal electrode or electrodes and the work. The arc and molten metal are shielded by a blanket of granular, fusible material on the work.

NEMA Standard 1-11-1983.

WELDING CURRENT

The amperage flowing in the welding circuit during the making of a weld.

NEMA Standard 11-17-1989.

WELDING POWER CIRCUIT

Any part of the system which is electrically energized by the welding power of the welding power source.

NEMA Standard 11-6-1975.

WELDING POWER SOURCE

A source of welding current and voltage for arc welding.

NEMA Standard 11-6-1975.

WIRE FEED CONTROL

The electrical apparatus or mechanical apparatus, or both, that control(s) the wire feed unit, the sequence of operations, and the services as required.

NEMA Standard 11-6-1975.

WIRE FEED SYSTEM

A system which applies a continuous filler wire to an arc or weld zone. The system usually includes the following elements: a gun assembly, gun cable assembly, wire feed unit, wire feed control, filler wire supply, and service line.

NEMA Standard 11-6-1975.

WIRE FEED UNIT

The apparatus that converts control power to mechanical power and transfers it to the filler wire. It usually includes a motor, speed reducing means, drive rolls, and filler wire guides. It may also include the wire feed control and filler wire supply.

NEMA Standard 11-6-1975.

Section 2
SERVICE CONDITIONS

2.1 GENERAL

Service conditions, other than those specified as usual, may have a detrimental effect on the welding apparatus. Such an effect depends upon the degree of departure from usual operating conditions and the severity of the environment to which the apparatus is exposed. Of principal concern are unusual service conditions which might cause abnormal deterioration of the insulation system, electrical breakdown or mechanical wear, resulting in premature failure.

Although past experience of the user may often be the best guide, the manufacturer of the welding equipment should be consulted for further information regarding any unusual service conditions which may increase the mechanical or thermal stresses on the equipment and, as a result, increase the chances for failure and possible hazard.

Authorized Engineering Information 11-6-1975.

2.2 USUAL SERVICE CONDITIONS

Equipment conforming to these standards shall be capable of operating in accordance with its rating under the following conditions:

1. Where the ambient temperature is in the rage of 0°C to 40°C.
2. Where the altitude is between sea level and 3300 feet (1000 meters).
3. When exposed to gases and dust produced by the welding arc.
4. When the input control voltage varies within ± 10 percent of input control voltage rating of the equipment.
5. When the input control frequency varies within ±10 percent of the input control voltage frequency rating of the equipment.

NEMA Standard 1-11-1983.

2.3 UNUSUAL SERVICE CONDITIONS

The manufacturer should be consulted if any unusual service conditions exist. Among such conditions are exposure to:

1. Combustible or conducting dusts.
2. Chemical fumes or flammable gases.
3. Rain, steam, or oil vapor.
4. Vermin infestation or atmosphere conducive to the growth of fungus.
5. Very dirty, corrosive, explosive, or abrasive environments.
6. High radiant or conducted heat.
7. Abnormal shock or vibration.
8. Nuclear radiation.
9. Severe weather conditions.
10. Seacoast and ship board conditions.
11. Continuous average relative humidity above 90 percent or below 10 percent.
12. Altitudes in excess of 3300 feet (1000 meters).

Authorized Engineering Information 1-11-1983.

Section 3
MECHANICAL CONSTRUCTION REQUIREMENTS

3.1 FRAMES AND ENCLOSURES—GENERAL STRENGTH CONSIDERATIONS

The frames and enclosures of a wire feed system and its elements shall be so formed and assembled that they will have the strength and rigidity necessary to withstand the normal service to which they are likely to be subjected without increasing the fire, shock, or other hazard of the system.

NEMA Standard 1-11-1983.

3.2 ENCLOSURE OF LIVE PARTS

Electrical parts, except those parts connected to the welding circuit, shall be so enclosed or located as to provide protection against accidental contact with uninsulated live parts.

NEMA Standard 11-17-1989.

3.3 OPENINGS IN ENCLOSURES

The suitability of an opening in the enclosure shall be determined in accordance with 3.3.1 and 3.3.2.

Any part of the outer enclosure that is intended to be opened or removed, without the use of tools, by the user of the equipment (to permit the attachment of accessories, to allow access to means for making operating adjustments, or for other reasons) shall be opened or removed prior to examination. The components of the welding power circuit on parts of the system that are not normally held by hand shall not be considered during this examination.

The components of the welding power circuit on the gun assembly or other parts that are normally held by hand shall be enclosed so as to comply with 3.3.1, except that these enclosures may be removable without the use of a tool. The contact tube area of the gun assembly shall not be considered during this examination.

NEMA Standard 11-17-1989.

3.3.1 Gun Assembly

An opening in the handle or housing of a gun assembly which is supported by hand during normal use shall meet the requirements of this standard if the probe illustrated in Figure 3-1, with a diameter D of 3⁄8 inch (9.53 mm), cannot be made to touch any uninsulated live part or film-coated wire when it is inserted point first into the opening to a maximum distance of 1 inch.

NEMA Standard 11-17-1989.

3.3.2 Openings in Apparatus Other Than the Gun Assembly

Openings in apparatus other than the gun assembly shall be judged as follows:

1. An opening that will permit entrance of a 0.750 inch (19 millimeter) diameter rod shall be suitable if there is no film-coated wire, uninsulated live part(s), hazardous moving part(s) or any combination thereof: (1) less than x inches (x millimeters) from the perimeter of the opening, or (2) within the volume generated by projecting the perimeter x inches (x millimeters) normal to its plane when x equals five times the diameter of the largest diameter rod [but not less than 4 inches (101.6 millimeters)] that can be inserted through the opening. (See Figure 3-2.)
2. An opening which will not admit a 3⁄4 inch (19.05 mm) diameter rod shall meet the requirements of this standard if:
   a. The probe illustrated in Figure 3-1, with a diameter D of 1⁄2 inch (12.70 mm) cannot be made to touch film-coated wire when inserted through the opening, and
   b. The probe illustrated in Figure 3-3 cannot be made to touch any uninsulated live parts when inserted through the opening.

NEMA Standard 11-17-1989.

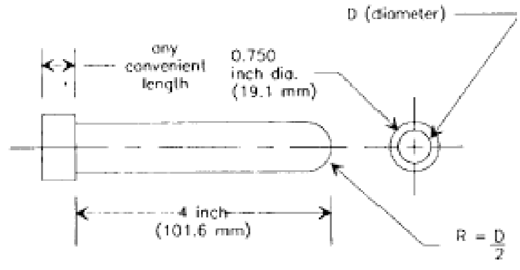

Figure 3-1
PROBE

3.4 ENCLOSURE CONSTRUCTION

Enclosures shall be constructed of either sheet metal or an insulating material.

If the enclosure is constructed from sheet metal, the thickness shall not be less than that given in Table 3-1.

If the enclosure is constructed of insulating material, the material shall meet the requirements for Class 94V-0 of the Underwriters Laboratories' UL 94, *Tests for Flammability of Plastic Materials for Parts in Devices and*

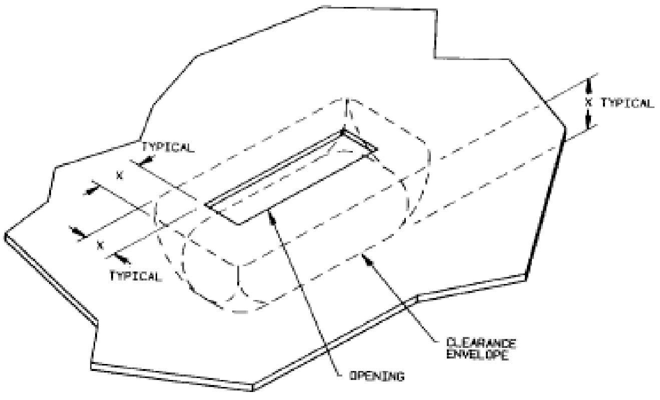

Figure 3-2
ENCLOSURE OPENING

Appliances. The enclosure shall have a mechanical strength at least equivalent to a sheet metal enclosure which is constructed in accordance with Table 3-1.

3.5 ROTATING PARTS

Rotating parts, such as motors, pulleys, belts, gears, drive rolls, etc., shall be so designed, enclosed, or guarded as to prevent accidental injury to personnel.

NEMA Standard 11-6-1975.

3.6 FILLER WIRE SUPPLY

The mounting of the filler wire supply, if integral with the wire feed unit, shall be so constructed as to have the strength and rigidity necessary to withstand the abuse to which it is likely to be subjected when fully loaded. Retaining means for the filler wire supply shall be so designed that the rotation and stops normally encountered will not in any way cause the filler wire supply to come loose. The supply or its mounting shall be insulated from the frame or enclosure of the wire feed unit.

NEMA Standard 11-6-1975.

3.7 CORROSION PROTECTION

Iron and steel parts, except bearings and other parts where protection is impractical, shall be suitably protected against corrosion if the deterioration of such unprotected parts would be likely to result in a hazardous condition.

NEMA Standard 11-6-1975.

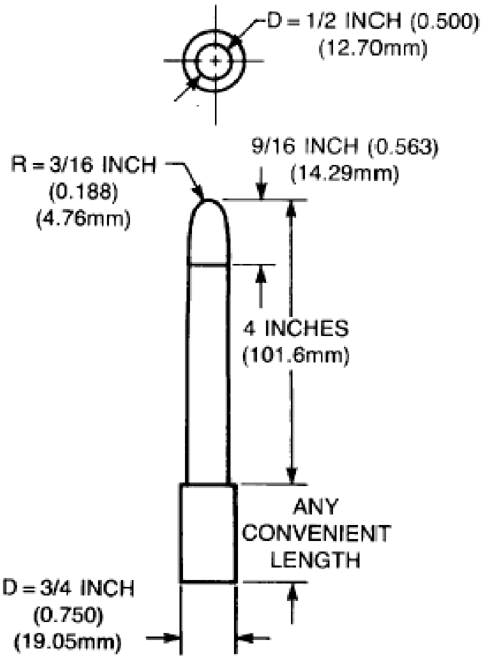

Figure 3-3
PROBE

Table 3-1
Thickness of Sheet Metal for Enclosures, Inches (mm)

Maximum Area of Any Surface	Maximum Dimension	Steel				Copper, Brass, Aluminum & Perforated & Expanded Steel	
		Without Supporting Frame		With Supporting Frame or Equivalent Reinforcing		Without Supporting Frame	With Supporting Frame or Equivalent Reinforcing
Sq. Inches (Sq. mm)	Inches(mm)	Zinc Coated	Uncoated	Zinc Coated	Uncoated		
6* ($38.7\times10^2 mm^2$)	3 (76)	0.023 (0.58)	0.020 (0.51)	0.023 (0.58)	0.020 (0.51)	0.023 (0.58)	0.023 (0.58)
36 ($232\times10^2 mm^2$)	8 (203)	0.029 (0.74)	0.026 (0.66)	0.023 (0.58)	0.020 (0.51)	0.036 (0.91)	0.029 (0.74)
90 ($581\times10^2 mm^2$)	12 (305)	0.034 (0.86)	0.032 (0.81)	0.023 (0.58)	0.020 (0.51)	0.045 (1.14)	0.029 (0.74)
135 ($871\times10^2 mm^2$)	18 (457)	0.045 (1.14)	0.042 (1.07)	0.034 (0.86)	0.032 (0.81)	0.058 (1.47)	0.045 (1.14)
360 ($2322\times10^2 mm^2$)	24 (610)	0.056 (1.42)	0.053 (1.35)	0.045 (1.14)	0.042 (1.07)	0.075 (1.90)	0.058 (1.47)
1200 ($7741\times10^2 mm^2$)	48 (1219)	0.070 (1.78)	0.067 (1.70)	0.056 (1.43)	0.053 (1.35)	0.095 (2.41)	0.075 (1.90)

*Volume of enclosure shall be not more than 12 cubic inches ($19.6\times10^{-5} m^3$).

3.8 SERVICE LINE HOSES

If supplied as part of the welding wire feed system and external to the enclosure, service line hoses and hose connection shall comply with the Rubber Manufacturers Association's referenced standards.

NEMA Standard 11-15-1991.

3.9 GUN ASSEMBLY

The materials used in the gun assembly shall be such that they will not be decomposed by the heat and radiation of the arc, thus resulting in dangerous levels of known toxic substances.

NEMA Standard 11-6-1975.

3.10 WATER COOLING

Any device or system which uses water for cooling shall be capable of operating at an inlet water pressure ranging from 30 psi (207kPa) to 75 psi (517kPa) and a water inlet temperature up to 49°C. For rating purposes, the water inlet pressure shall be 30 psi (207kPa) at a water inlet temperature of 49°C.

NEMA Standard 11-6-1975.

3.11 DROP TESTING

3.11.1 Handles, eyes or lugs, which are provided for the purpose of lifting an assembled wire feed unit or system, shall be capable of withstanding a free-fall jerk test. This test shall be conducted with the maximum weight of filler wire and shielding medium recommended if such storage means are provided as a part of the assembled unit or system. To conduct this test, the unit or system shall be suspended aloft from a rigid member by a chain or cable attached to the lifting device. The unit or system shall be positioned above and away from any surface that it might strike during the test process.

The chain or cable suspension assembly shall be arranged so that a free fall of at least 6 inches (152.4 mm) takes place before the unit is caught in suspension, bringing the full force to bear on the lifting device. Three such falls shall be made.

3.11.2 An assembled wire feed unit or system, complete with the full storage means described in 3.11.1, shall be capable of withstanding a drop test. This test shall consist of three drops onto a hard and rigid surface from a height of not less than 6 inches (152.4 mm). These drops shall be so arranged that each drop will strike the unit or system on a bottom edge different from that of any other drop.

3.11.3 After the foregoing tests, the assembled wire feed unit or system shall meet the requirements of this publication (other than 3.11.1 and 3.11.2) in all respects, even though there may be some deformation of the structural or case parts.

NEMA Standard 11.17-1989.

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Section 4
ELECTRICAL CONSTRUCTION REQUIREMENTS

4.1 SERVICE LINE CORDS, CABLES, AND CONNECTIONS EXTERNAL TO THE ENCLOSURE

4.1.1 Welding current cables shall be of the flexible type, specifically designed and constructed to withstand the rigors of welding service, and of a size adequate to carry the rated current.

NEMA Standard 11-6-1975.

4.1.2 Flexible cords shall be Type S, SO, SJ, or SJO and shall have a current carrying capacity not less than the current rating of the circuit at its rated duty cycle.

NEMA Standard 11-17-1989.

4.1.3 Strain relief shall be provided for flexible cords and shall be capable of withstanding a 35 pound (156 N) tensile force for a period of 1 minute without transmitting mechanical strain to terminals, splices, or interior wiring.

NEMA Standard 11-17-1989.

4.1.4 Means shall be provided to prevent flexible cords from being pushed into the enclosure through the cord-entry hole if such displacement is likely to (1) subject the cord to mechanical damage, (2) expose the cord to a temperature higher than that for which it is suitable, or (3) reduce spacings (such as to a metal strain relief clamp) below the values given elsewhere in this publication.

NEMA Standard 11-6-1975.

4.2 WIRE FEED UNIT AND CONTROL

4.2.1 Input Control Voltage Rating

Where the wire feed unit and control are not within the enclosure of the welding power source, the input control voltage rating of the wire feed system shall not exceed 115 volts rms.

NEMA Standard 11-17-1989.

4.2.2 Selection of Electrical Components

Electrical components shall be selected so that their rated temperature will not be exceeded when the wire feed system is operating at rated load under usual service conditions and so that their electrical ratings are suitable for the application.

NEMA Standard 11-17-1989.

4.2.3 Internal Wiring

The internal wiring shall consist of wires which are recognized for the particular application with respect to the temperature, current, voltage, exposure to oil or grease, and other conditions of service to which they are likely to be subjected.

The wiring shall be so arranged or protected that no damage to the conductor insulation will occur from contact with any rough, sharp, or moving part.

All joints and connections shall be mechanically secure and shall provide adequate and reliable electrical contact without mechanical strain.

An uninsulated conductor, if used within an enclosure, shall be so supported that the spacings given elsewhere in this publication will be maintained.

NEMA Standard 11-17-1989.

4.2.4 Mounting of Current Carrying Parts

Insulating washers, bushings, sheets, etc., for the mounting or insulation of current carrying parts shall be of moisture-resistant material which will not be damaged by the temperature to which they will be subjected during operation at rated load under usual service conditions.

NEMA Standard 11-17-1989.

4.2.5 Spacings

Spacings through air or over surfaces between an uninsulated live part and metallic enclosure or frame shall be not less than 1/8 inch (3.2 mm).

Spacings through air or over surfaces between live uninsulated wiring terminals with a difference in potential shall be not less than 1/8 inch (3.2 mm).

The foregoing spacings shall not apply to wiring devices, connectors, switches, lamp holders, printed circuit boards, motors or other components for which spacings are given in the standards covering such components.

NEMA Standard 11-17-1989.

4.2.6 Grounding

All exposed non-current carrying metal parts which are likely to become energized by input control power (other than that from the welding power circuit) under abnormal conditions shall have metal-to-metal contact or be otherwise electrically bonded together and shall be provided with a means for grounding. The grounding means shall be secured to the frame or enclosure by a screw or fastening that is not likely to be removed during any servicing operation other than the removal of the service line. Solder alone shall not be used for securing the grounding means.

NEMA Standard 11-17-1989.

4.2.7 Overload Protection

Fuses, circuit breakers and similar devices shall be provided to limit electrical control power during protracted periods in the internal wiring or electrical components of the unit that would cause fire or other hazardous conditions.

NEMA Standard 1-11-1983.

4.3 GUN ASSEMBLY AND GUN CABLE ASSEMBLY

4.3.1 Except where the wire feed system is powered only from the welding power circuit, the voltage of any gun switch circuit shall be supplied from an isolated voltage source and shall not exceed 35 volts rms or 50 volts direct current. When the wire feed system is powered only from the welding arc, the voltage of any gun switch circuit shall not exceed the open circuit voltage rating of the welding power source.

4.3.2 Since the grounding of exposed metal parts on the gun assembly may constitute a hazard, such parts shall not be grounded.

4.3.3 Spacings through air or over surfaces between uninsulated live metal parts and exposed dead metal parts shall be not less than 1/16 inch (1.6 mm).

Spacings through air or over surfaces between live uninsulated metal parts with a difference in potential shall be not less than 1/16 inch (1.6 mm).

The foregoing spacings shall not apply to wiring devices, connectors, switches, lamp holders, printed circuit boards, motors, or other components for which spacings are given in the standards covering such components.

4.3.4 The insulation of current carrying parts shall be of moisture-resistant material which will not be damaged by the temperature to which the parts will be subjected when they are operating at rated load under usual service conditions.

NEMA Standard 11-17-1989.

4.3.5 Supply Lines

4.3.5.1 The cable which carries welding current to the gun assembly, whether water cooled or convection cooled or incorporated into a unified assembly, shall be selected so that the surface temperature of the cable or unified assembly will not exceed the temperatures given in Table 5-1. The test shall be made in accordance with 5.3.1.2.

NEMA Standard 11-17-1989.

4.3.5.2 Flexible control cords or control conductors shall be suitable for the particular application with respect to the temperature, current, voltage, exposure to oil and grease, and other conditions of service to which they are likely to be subjected. The connection at each end of the control cords or control conductors shall prevent any mechanical stress from being transmitted to the terminals, splices, or interior wiring of the gun assembly or wire feed unit.

Means shall be provided to prevent flexible control cords or control conductors from being pushed into the enclosure through the cord-entry hole if such displacement is likely to (a) subject the cord or conductor to mechanical damage or (b) expose the cord or conductor to a temperature higher than that for which it is suitable or (c) reduce spacings (such as to a metal strain relief clamp) below the values given elsewhere in this publication.

NEMA Standard 11-6-1975.

4.4 HIGH-POTENTIAL TEST AND INSULATION RESISTANCE

4.4.1 High-Potential Test

Each electrical circuit of wire feed system shall be capable of withstanding for 1 minute, without breakdown, the application of a 60-hertz essentially sinusoidal test voltage of 1000 volts plus twice the rated voltage of the circuit. Alternatively, for production-line testing, a test voltage which is 20 percent greater than that used for a 1 minute test shall be applied for 1 second.

The test voltage shall be applied successively between each input circuit and the enclosure and between each output circuit and the enclosure, with circuits not under test connected to the enclosure.

Circuit interrupters such as relays, switches, etc., shall be bridged during the test so that the entire circuitry is tested. The welding power circuit, including all metal parts such as drive rolls, filler wire guides, filler wire supply means, etc., contacting the welding power circuit, shall be considered as a separate input circuit.

The high-potential test shall be made as a part of the manufacturer's tests on new and completely assembled machines.

Devices such as meters, rectifiers, capacitors, lamp holders, switches, fractional-horsepower motors, rheostats, electronic equipment, ground detectors, etc., which do not fall within the scope of this publication but for which there are standards for high-potential tests and which require lower test voltages than called for in this publication, shall be grounded, short-circuited or disconnected before the high-potential tests are made.

NEMA Standard 11-17-1989.

4.4.2 Insulation Resistance

The insulation resistance of the gun assembly and other parts which are normally held by hand shall be not less than 1.0 megohm when a dc test voltage of 500 volts is applied between live parts and the external surfaces which are normally touched during the welding process.

Prior to being tested, a sample unit shall be kept in an enclosure for 48 hours at room temperature and at a relative humidity of 90 to 95 percent. Immediately upon its removal from the enclosure, the unit shall be wrapped in metal foil. The foil shall be in intimate contact with the handle and with all exposed metal parts which are normally accessible. A dc test voltage of 500 volts shall be applied between the foil and the live parts of the welding power and control circuits.

NEMA Standard 11-6-1975.

Section 5
RATING AND PERFORMANCE

5.1 RATING OF WIRE FEED SYSTEM

The rating of a wire feed system and its elements shall include the minimum information listed below. The rating of a wire feed system element shall include the information listed below where applicable.

1. Rated current.
2. Maximum and minimum filler wire-size.
3. Types of filler wire.
4. Rated speed range for each size of filler wire.
5. Duty cycle.
6. Input control voltage, current, and frequency.
7. Shielding gas(es).

NEMA Standard 1-11-1983.

5.2 PERFORMANCE

5.2.1 Feeding

The wire feed system shall be capable of feeding through the gun and gun cable assemblies in a smooth and uniform manner each size and type of filler wire over its rated speed range as recommended by the manufacturer under the following conditions:

1. The filler wire conduit, when used, shall be positioned so as to have a 12 inch (0.3 meter) radius loop beginning at the wire feeder. If the conduit is long enough to form one complete loop, any remaining length shall be straight.
2. If the filler wire supply has an overrun limiting device, the device shall be adjusted so that not more than 40 degrees of spool rotation will take place when the wire feed unit is stopped, with the maximum amount of filler wire stored on the spool.
3. Usual service conditions, see 2.2.
4. All components are in place, adjusted, and in the condition in which they are normally supplied for welding.

NEMA Standard 11-17-1989.

5.2.2 Loading

Under the conditions outlined in 5.2.1 and with the filler wire size and rated speed that produces the most severe loading conditions within the rating of the wire feed unit, the loading on the unit shall be not greater than 75 percent of maximum load.

NEMA Standard 1-11-1983.

5.3 TEMPERAURE RISING

5.3.1 Wire Feed System

5.3.1.1 When a wire feed system is a separate unit, it shall be capable of operating indefinitely under maximum load at a repetitive duty cycle of 6 minutes on and 4 minutes off without causing any component to exceed its rated temperature. An arc welding power source with integral wire feed unit shall be capable of operating indefinitely at its rated current and duty cycle without causing any component to exceed its rated temperature. However, for water-cooled aparatus, see 3.10.

NEMA Standard 11-15-1991.

Under these conditions, the temperature on any external surface that may be contacted by the user (other than those parts of the gun assembly from the handle to the end of the contact tube or nozzle) shall not exceed the values given in Table 5-1 at an ambient temperature of 25°C. If the test is conducted at an ambient temperature other than 25°C, the results shall be corrected to 25°C.

NEMA Standard 11-17-1989.

Table 5-1
MAXIMUM TEMPERATURES ON EXTERNAL SURFACES

Location and/or Type of Surface	Composition of Surface	
	Metallic	Non-metallic
1. Handle or knob grasped for lifting, carrying, or holding:	50°C	60°C
2. Handle, knob, or surface of the enclosure that is intended to be contacted during normal use but does not require continuous holding:	60°C	85°C
3. Surface subjected to casual contact:	70°C	95°C

5.3.1.2 Additionally, the wire feed system shall meet the requirements of 5.3.1.1 when it is cycled for 4 seconds on and 2 seconds off during the 6 minute on time of the duty cycle specified in 5.3.1.1.

5.3.2 Gun and Gun Cable Assemblies

The testing of the gun and gun cable assemblies for the temperatures specified in 5.3.1 shall be conducted as follows:

1. A weld bead shall be deposited on a horizontal work surface which may be water cooled.
2. The rate of travel shall be selected so that a continuous following weld pool is maintained.
3. The filler wire entering the weld pool shall be perpendicular to the horizontal surface and the gun assembly handle shall be 90 degrees from the direction of travel.

4. Welding parameters shall be those shown in:
   Figure 5-1, Part 1—for flux cored arc welding without gas.
   Figure 5-1, Part 2—for flux cored arc welding with CO_2 gas.
   Figure 5-2, Part 1—for gas metal arc welding with CO_2 gas and solid electrode.
   Figure 5-3— for gas-tungsten arc welding with filler wire.

   The welding voltage shown on the curves in Figures 5-1 and 5-2 is measured from the gun assembly to the work. Welding process parameters have a tolerance of plus or minus five percent.
5. For validating the rated current of the gun and gun cable assembly for submerged arc welding, the electrode shall be copper-coated (see AWS A5.17) and welding polarity shall be electrode positive.
6. In each case, the test shall be run with that filler wire size within the rated range of the gun and gun cable assembly that produces the highest temperature.

NEMA Standard 1-11-1983.

5.4 OTHER PERFORMANCE DATA

5.4.1 When performance data is given for other gases (see 5.4.3 and Figure 5-2, Part 2), or other duty cycles, or both, in addition to the specified 60 percent duty cycle, the tests performed shall comply with the procedures and limits as given in this publication in all other respects.

NEMA Standard 11-17-1989.

5.4.2 When performance data is given for the maximum regulation of filler wire speed with respect to load, to input control voltage, and to warm up, it shall be calculated as follows:

1. Maximum Regulation of Filler Wire Feed Speed With Respect to Load

The maximum variation in wire feed speed at any present speed within the rated speed range shall be determined by:

$$\left(\frac{S_1 - S_2}{S_2}\right) \times 100 = {}^{R}(\text{Load})$$

where—

^{R}(Load) = Speed regulation due to load change (in percent).
S_1 = Wire feed speed at 1/2 maximum load.
S_2 = Wire feed speed at maximum load.

The wire feed unit and wire feed control shall be operated for at least 1/2 hour at 1/2 their maximum load before making this test.

2. Maximum Regulation of Filler Wire Feed Speed with Respect to Input Control Voltage (ICV)

The maximum variation in wire feed speed throughout all loads and speeds within the rated speed range when the input control voltage is varied within plus or minus 10 percent of the rated input control voltage shall be determined by:

$$\left(\frac{S_1 - S_2}{S_2}\right) \times 100 = {}^{R}(\text{ICV})$$

where —

^{R}(ICV) = Speed regulation due to ICV change (in percent)
S_1 = Wire feed speed at ± 10 percent of rated ICV.
S_2 = Wire feed speed at rated ICV.

The wire feed unit and wire feed control shall be operated for at least 1/2 hour at 1/2 their maximum load before making this test.

NEMA Standard 11-17-1989.

3. Maximum Regulation of Filler Wire Feed Speed with Respect to Warm-Up

The maximum variation in wire feed speed at maximum load throughout the rated speed range due to the rise in the temperature of components from the ambient temperature to the operating temperature shall be determined by:

$$\left(\frac{S_1 - S_2}{S_2}\right) \times 100 = {}^{R}(\text{T.Rise})$$

where —

^{R}(T. Rise) = Speed regulation due to temperature rise (in percent)
S_1 = Wire feed speed at ambient temperature.
S_2 = Wire feed speed at operating temperature.

The ambient temperature shall be stated and maintained within a tolerance of ±5°C (9°F).

NEMA Standard 11-6-1975.

5.4.3 Other Ratings

When gun and cable assembly are to be rated for argon enriched gases, the welding parameters shall be those shown in Figure 5-2, Part 2, Gas Metal Arc Welding with Argon Gas and Solid Electrode.

NEMA Standard 11-17-1989.

Section 6
MARKINGS

6.1 WIRE FEED NAMEPLATE

The wire feed unit, or the major element of the system when not part of an arc welding power source with integral wire feed unit, shall be plainly marked in a location where the markings will be readily visible, with the following minimum information:

1. Manufacturer's name and model number.
2. Input control voltage.
3. Input control frequency.
4. Input control current in amperes at maximum load.
5. The words "NEMA EW 3."

NEMA Standard 11-15-1991.

6.2 GUN ASSEMBLY OR GUN CABLE ASSEMBLY MARKING

Any gun assembly or gun cable assembly designed for use with feed systems, which can be used with arc welding power sources of different output ratings shall have a single marking located where it will be readily visible and plainly marked with the following minimum information: (See 5.3)

1. Welding current rating in amperes at 60 percent duty cycle.
2. The words "60 Percent Duty Cycle-CO_2" for guns designed for use with gas or the words "60 Percent Duty Cycle" for guns designed for use without gas. If abbreviated, Duty Cycle shall be shown as "D/C."
3. The words "NEMA EW 3."

NEMA Standard 11-15-1991.

FIG. 5-1 PART 1

FLUX CORED ARC WELDING WITHOUT GAS

FOR VALIDATING THE RATED CURRENT OF THE GUN AND CABLE ASSEMBLY, THE WORST CASE CONDITION TAKEN FROM THE CURVES BELOW SHALL BE USED.

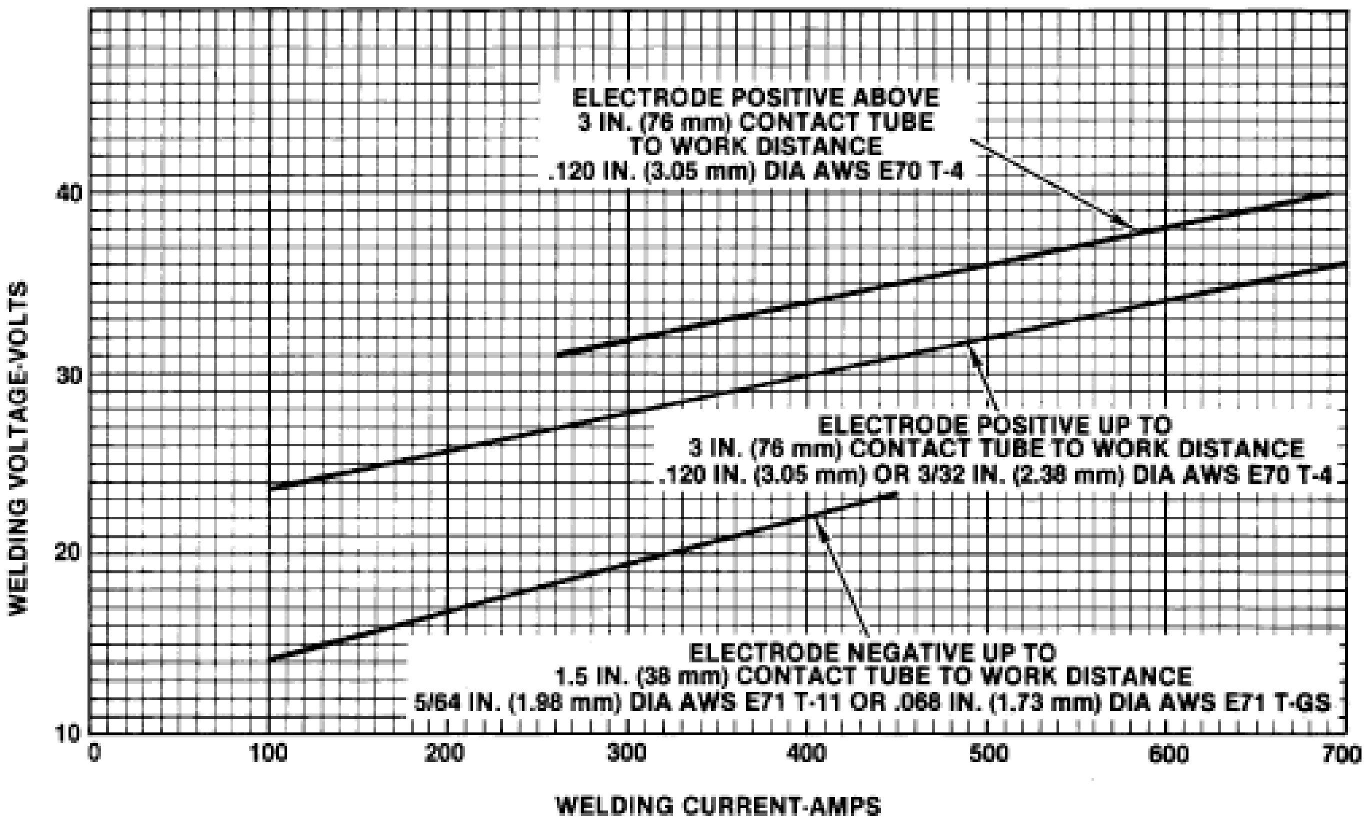


FIG. 5-1 PART 2

FLUX CORED ARC WELDING WITH CO_2 GAS

FOR VALIDATING THE RATED CURRENT OF THE GUN AND CABLE ASSEMBLY, THE WORST CASE CONDITION TAKEN FROM THE CURVES BELOW SHALL BE USED.

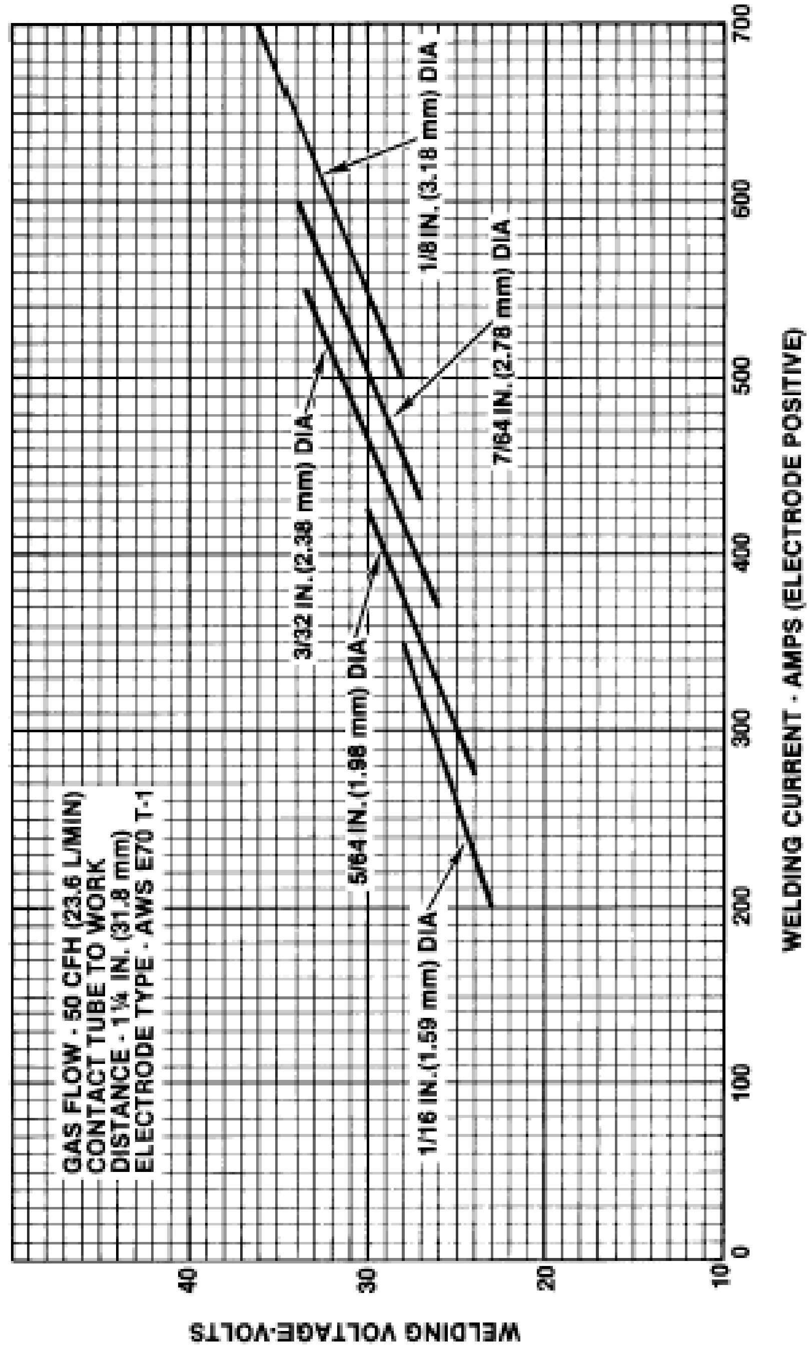


FIG. 5-2 PART 1

GAS METAL ARC WELDING WITH CO_2 GAS AND SOLID ELECTRODE

FOR VALIDATING THE RATED CURRENT OF THE GUN AND CABLE ASSEMBLY, THE WORST CASE CONDITION TAKEN FROM THE CURVES BELOW SHALL BE USED.

ELECTRODE DIA	CONTACT TUBE TO WORK DISTANCE	CO_2 GAS FLOW
.030 IN. (.76 mm)	5/16 IN. (7.94 mm)	30 CFH (14.1 L/MIN)
.035 IN. (.89 mm)	3/8 IN. (9.52 mm)	30 CFH (14.1 L/MIN)
.045 IN. (1.14 mm)	1/2 IN. (12.7 mm)	30/50* CFH (14.1/23.6* L/MIN)
1/16 IN. (1.59 mm)	3/4 IN. (19 mm)	50 CFH (23.6 L/MIN)

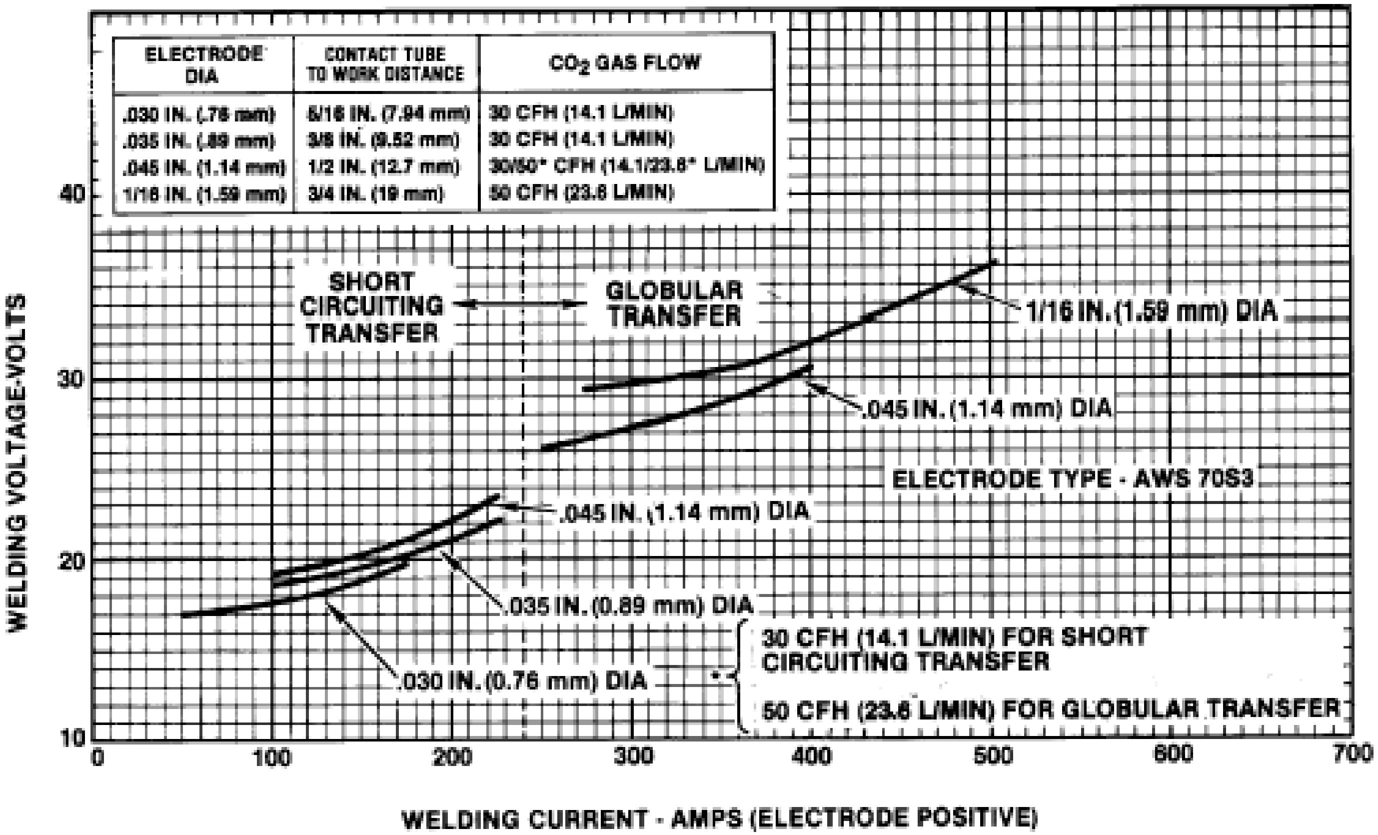


FIG. 5-2 PART 2

GAS METAL ARC WELDING WITH ARGON GAS AND SOLID ELECTRODE

FOR VALIDATING THE RATED CURRENT OF THE GUN AND CABLE ASSEMBLY, THE WORST CASE CONDITION TAKEN FROM THE CURVES BELOW SHALL BE USED.

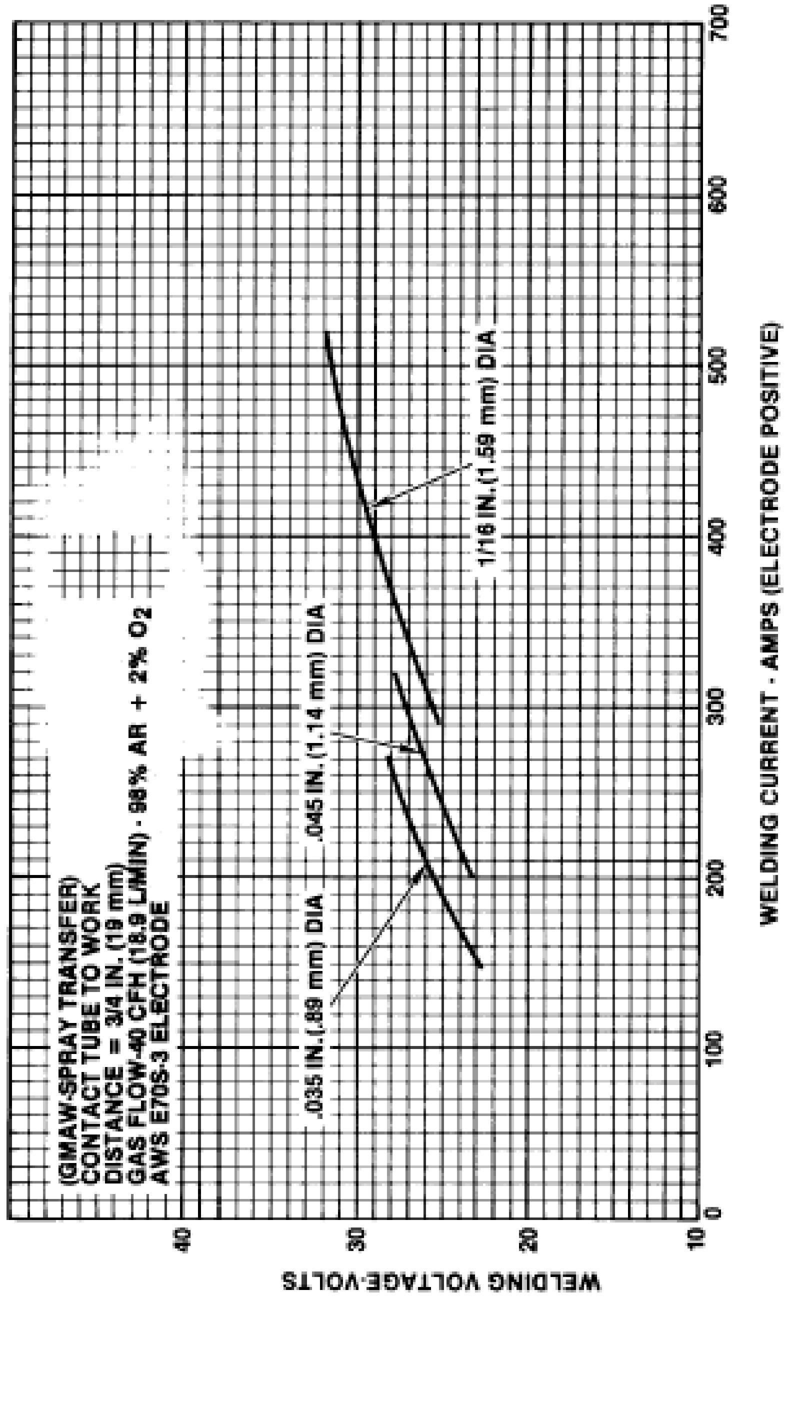
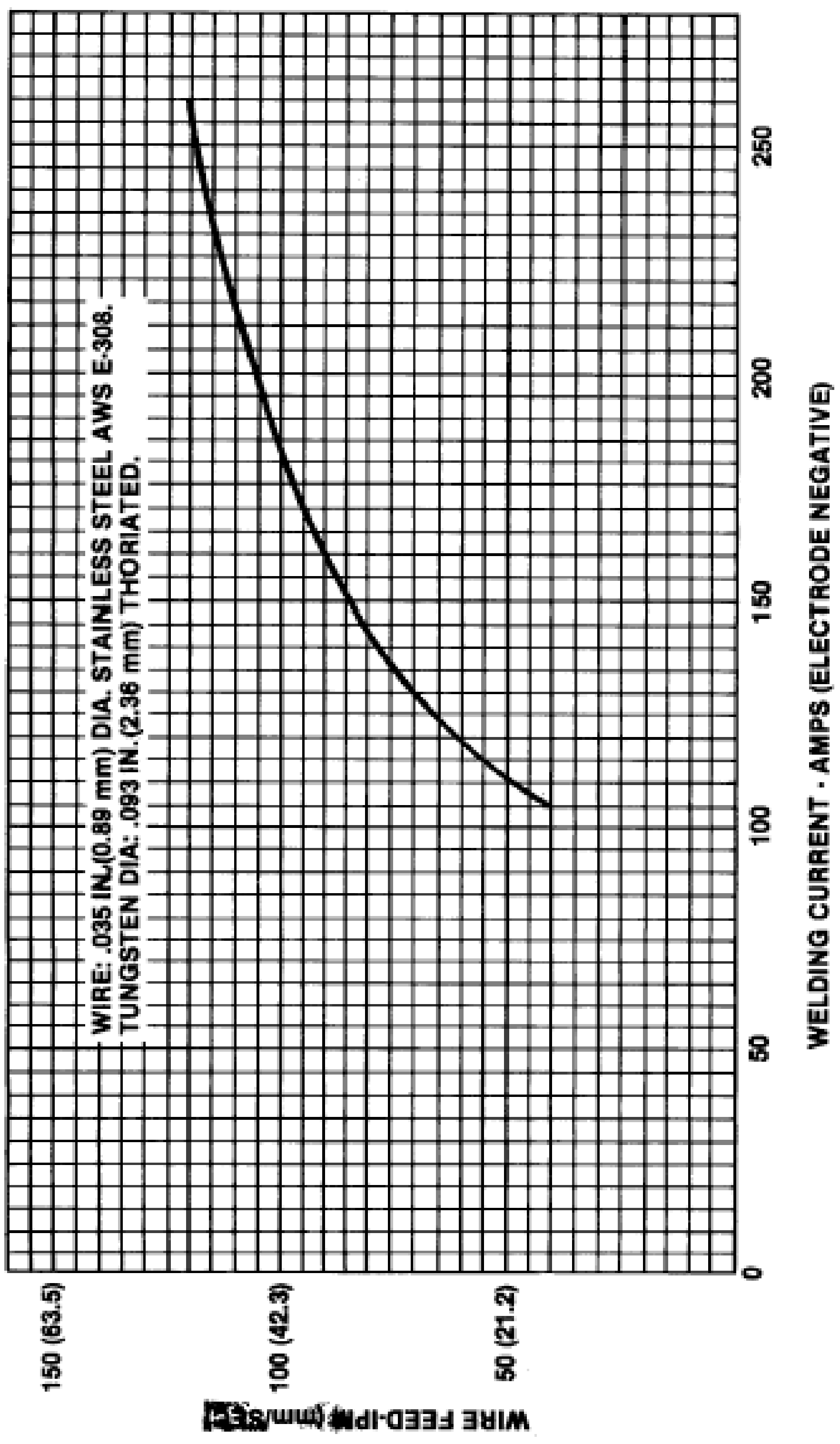


FIG. 5-3

GAS TUNGSTEN ARC WELDING WITH FILLER WIRE

FOR VALIDATING THE RATED CURRENT OF THE GUN AND CABLE ASSEMBLY, THE FOLLOWING PARAMETERS SHALL BE USED.



NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status, are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below.

Purpose of Standards

National Electrical Manufacturers Association standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist purchasers in selecting and obtaining the proper product for their particular needs. Existence of a National Electrical Manufacturers Association standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard. *(Standardization Policies and Procedures, p. 1)*

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process, or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Standardization Policies and Procedures, p. 2)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the Standards Publication may be capable of otherwise equivalent performance.

(Standardization Policies and Procedures, p.8)

Categories of Standards

National Electrical Manufacturers Association Standards are of two classes:

1. NEMA Standard, which relates to a product, process, or procedure commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

(Standardization Policies and Procedures, pp. 7 & 16)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote on the standard.

(Standardization Policies and Procedures, pp. 7 & 16)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment, and/or approval, and which has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon.

(Standardization Policies and Procedures, pp. 7 & 16)

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

ARC WELDING SECTION
OF THE
NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

MEMBER COMPANIES

Alloy Rods Corporation
The ESAB Group
Hanover, PA 17331

Century Manufacturing Company
Minneapolis, MN 55431

C K Systematics, Inc.
Auburn, WA 98002

Harris Calorific Division
The Lincoln Electric Company
Gainesville, GA 30501

Hobart Brothers Company
Troy, OH 45373

Hypertherm, Incorporated
Hanover, NH 03755

Inco Alloys International, Inc.
Newton, NC 28658

The Lincoln Electric Company
Cleveland, OH 44117

L-TEC Welding & Cutting Systems
The ESAB Group
Florence, SC 29501

Miller Electric Mfg. Company
Appleton, WI 54912

National Standard Company
Niles, MI 49120

Pow Con, Inc.
San Diego, CA 92126

Sandvik Steel Company
Welding and Wire Division
Scranton, PA 18501

Teledyne McKay
York, PA 17405

Thernadyne Industries, Inc.
St. Louis, MO 63105

ANEXO 2

HOJAS DE PROCEDIMIENTOS Y RECOLECCIÓN DE DATOS PARA LA PRUEBA DE ALTO POTENCIAL

	CENTRO DE CERTIFICACIÓN DE MÁQUINAS SOLDADORAS "CECMASOL"		Página 1/3 Revisión Nº 01
	PROCEDIMIENTO PARA REALIZAR LAS PRUEBAS DE ALTO POTENCIAL	**S4 – P – 01**	Ultima Revisión 03-08-2006

S4 – P – 01

ELABORADO POR	FECHA DE ELABORACIÓN	APROBADO POR	FECHA DE APROBACIÓN

Ing. Homero Barragán

Ing. Ricardo Aguirre

REVISIÓN Nº	REVISADO POR	OBSERVACIONES

	CENTRO DE CERTIFICACIÓN DE MÁQUINAS SOLDADORAS "CECMASOL"		Página 2/3 Revisión Nº 01
	PROCEDIMIENTO PARA REALIZAR LAS PRUEBAS DE ALTO POTENCIAL	S4 – P – 01	Ultima Revisión 03-08-2006

OBJETIVO

Establecer el procedimiento a seguir para realizar las pruebas de alto potencial de la máquina soldadora, garantizando la seguridad del personal y la calidad de la prueba.

ALCANCE

Se cubrirá todo lo relacionado con las pruebas de alto potencial para las máquinas soldadoras en general y los sistemas semiautomáticos de alimentación de electrodo continuo, indicando como se deben conectar los equipos, realizar las pruebas y finalizando con el informe de resultados.

AUTORIDADES Y RESPONSABILIDADES

- El ayudante del Sector 4 será el encargado de llevar a cabo esta prueba.
- El ingeniero encargado del Sector 4 debe ser quien conecte los instrumentos.
- El ingeniero encargado del Sector 4 debe ser el responsable de ver que se cumpla a cabalidad con este procedimiento y de ser quien juzgue si la máquina pasa o no la prueba, así como de llenar el Informe de Resultados de la Prueba.

DESARROLLO

1. Verificar que la máquina soldadora esté apagada.
2. Abrir la máquina soldadora y desconectar, poner a tierra o puentear, todos los artefactos que no van a intervenir en la prueba, tales como medidores, rectificadores, capacitares, interruptores, equipamiento electrónico, etc.
3. Calcular los voltajes de prueba que se deben aplicar a las diferentes partes de la máquina soldadora.
4. Conectar los terminales del generador de CA entre la entrada del circuito que va a ser probado y su carcasa o partes de montaje, por ejemplo: el circuito de entrada y la carcasa.

5. Verificar en el generador de CA que la frecuencia del voltaje de prueba a ser aplicado sea de 60 Hz.
6. Antes de encender el generador de CA asegurarse de que ninguna persona se encuentre a menos de dos metros de la máquina soldadora.
7. Encender el generador de CA y aplicar el voltaje de prueba calculado para el circuito que está siendo probado por un minuto.
8. Apagar el generador y esperar 10 segundos antes de acercarse a la máquina soldadora.
9. Repetir los pasos del 4 al 8 para los demás circuitos que deben ser probados.
10. Repetir los pasos del 1 al 9 para los sistemas semiautomáticos de alimentación de electrodo continuo.
11. Llenar el Informe de Resultados.

NOTA:

La temperatura a la cual debe ser hecha esta prueba es a la temperatura ambiente o a cualquier temperatura superior obtenida durante la Prueba de Temperatura y Presión.

REGISTROS

Informe: S4 – I – 01 "Informe de Resultados de las Pruebas de Alto Potencial".

	CENTRO DE CERTIFICACIÓN DE MÁQUINAS SOLDADORAS "CECMASOL"		Página 1/2 Revisión Nº 01
	INFORME DE RESULTADOS DE LAS PRUEBAS DE ALTO POTENCIAL	S4 – I – 01	Ultima Revisión 03-08-2006

INFORME DE RESULTADOS DE LAS PRUEBAS DE ALTO POTENCIAL

Fecha: ...... de .... del 20......
Orden de Trabajo Nº:.....................................
Hora de Finalización de la Prueba:...................
CUMPLE CON LA PRUEBA: SI......... NO.........

PARA LA MÁQUINA SOLDADORA

Cálculo de los voltajes de Prueba:

El voltaje de prueba a ser aplicado se lo calcula de la siguiente manera:

$$V = [1000 + (2xV_c)]x0.85 \quad (Vrms)$$

Donde:

V = Voltaje de Prueba

Vc = Voltaje nominal del circuito bajo prueba.

Voltaje Aplicado Entre:		Voltaje Nominal del circuito bajo prueba	Voltaje de Prueba (Vrms)	Cumple	
				SI	NO
	Carcasa				
	Carcasa				
	Carcasa				
	Carcasa				
	Carcasa				
	Carcasa				

	CENTRO DE CERTIFICACIÓN DE MÁQUINAS SOLDADORAS "CECMASOL"		Página 2/2 Revisión Nº 01
	INFORME DE RESULTADOS DE LAS PRUEBAS DE ALTO POTENCIAL	S4 – I – 01	Ultima Revisión 03-08-2006

PARA EL SISTEMA SEMIAUTOMÁTICO DE ALIMENTACIÓN DE ELECTRODO CONTINUO.

Cálculo de los voltajes de Prueba:

El voltaje de prueba a ser aplicado se lo calcula de la siguiente manera:

$$V = [1000 + (2xV_c)]x0.85 \quad (Vrms)$$

Donde:

V = Voltaje de Prueba

Vc = Voltaje nominal del circuito bajo prueba.

Voltaje Aplicado Entre:		Voltaje Nominal del circuito bajo prueba	Voltaje de Prueba (Vrms)	Cumple	
				SI	NO
	Carcasa				
	Carcasa				
	Carcasa				
	Carcasa				
	Carcasa				
	Carcasa				

OBSERVACIONES: ....

....

....

....

Responsable de la prueba: ....

________________________ ________________________

(f) Responsable de la Prueba (f) Ingeniero encargado del Sector 4

ANEXO 3

CARACTERÍSTICAS DE LOS ALAMBRES MAGNETO REDONDOS

Características Alambres Magneto Redondos

Normas de Fabricación NEMA MW-1000, NTC 361

Calibre	Alambre Desnudo		Capa Sencilla (1)			Capa Doble			Máxima Tensión de Embobinado (2)	Resistencia D.C. a 20°C	Capacidad de Corriente (3) (A)	
	Diámetro Nominal	Peso Total Aprox.	Mínimo Incremento	Máximo Diámetro	Longitud Aproximada	Mínimo Incremento	Máximo Diámetro	Longitud Aproximada				
AWG	mm	kg/km	mm	mm	m/kg	mm	mm	m/kg	kg	Ohm/km	155°C	200°C
6	4,115	118,23	-	-	-	0,091	4,244	8,4	79,5	1,296	87	131
7	3,665	93,79	-	-	-	0,089	3,787	10,6	63,1	1,634	69	104
8	3,264	74,39	-	-	-	0,089	3,383	13,3	50,0	2,060	55	83
9	2,906	58,96	-	-	-	0,086	3,023	16,8	39,7	2,599	44	65
10	2,588	46,76	-	-	-	0,086	2,703	21,2	31,5	3,278	35	52
11	2,304	37,06	-	-	-	0,084	2,416	26,7	24,9	4,135	27	41
12	2,052	29,40	-	-	-	0,081	2,159	33,6	19,8	5,213	22	33
13	1,829	23,36	-	-	-	0,081	1,935	42,2	15,7	6,562	17	26
14	1,628	18,51	0,041	1,692	53,5	0,081	1,732	53,1	12,4	8,283	14	21
15	1,450	14,68	0,038	1,509	67,4	0,076	1,549	66,9	9,87	10,44	11	16
16	1,290	11,62	0,036	1,349	85,1	0,074	1,384	84,4	7,82	13,19	8,6	13
17	1,151	9,25	0,036	1,207	106,9	0,071	1,240	105,9	6,22	16,57	6,8	10
18	1,024	7,32	0,033	1,077	135,0	0,066	1,110	133,7	4,92	20,93	5,4	8,1
19	0,912	5,81	0,030	0,963	170,0	0,064	0,993	168,2	3,91	26,39	4,3	6,4
20	0,813	4,62	0,030	0,864	213,7	0,061	0,892	211,3	3,10	33,21	3,4	5,1
21	0,724	3,66	0,028	0,770	269,2	0,056	0,800	266,0	2,46	41,88	2,7	4,1
22	0,643	2,89	0,028	0,686	341,1	0,053	0,714	336,7	1,94	53,09	2,1	3,2
23	0,574	2,30	0,025	0,617	427,0	0,051	0,643	421,1	1,55	66,63	1,7	2,6
24	0,511	1,82	0,025	0,551	538,8	0,048	0,577	531,1	1,23	84,07	1,3	2,0
25	0,455	1,445	0,023	0,493	678,9	0,046	0,516	668,4	0,972	106,0	1,07	1,6
26	0,404	1,140	0,023	0,439	859,1	0,043	0,462	844,6	0,767	134,5	0,84	1,26
27	0,361	0,910	0,020	0,396	1076	0,041	0,419	1057	0,612	168,4	0,67	1,01
28	0,320	0,7150	0,020	0,356	1362	0,041	0,373	1337	0,481	214,4	0,53	0,79
29	0,287	0,5751	0,018	0,320	1695	0,038	0,338	1658	0,387	266,5	0,43	0,64
30	0,254	0,4505	0,018	0,284	2160	0,033	0,302	2110	0,303	340,3	0,33	0,50
31	0,226	0,3566	0,015	0,254	2725	0,030	0,274	2653	0,240	429,8	0,26	0,40
32	0,203	0,2877	0,015	0,231	3367	0,028	0,249	3279	0,194	532,7	0,21	0,32
33	0,180	0,2262	0,013	0,206	4274	0,025	0,224	4149	0,152	677,5	0,17	0,25
34	0,160	0,1787	0,013	0,183	5405	0,023	0,198	5263	0,120	857,5	0,13	0,20
35	0,142	0,1408	0,010	0,163	6849	0,023	0,178	6667	0,0947	1089	0,105	0,16
36	0,127	0,1126	0,010	0,147	8621	0,020	0,160	8333	0,0758	1361	0,083	0,13
37	0,114	0,09074	0,010	0,135	10638	0,018	0,145	10309	0,0610	1689	0,068	0,101
38	0,102	0,07264	0,008	0,119	13514	0,018	0,130	12987	0,0489	2110	0,053	0,080
39	0,089	0,05531	0,008	0,104	17544	0,015	0,114	16949	0,0372	2771	0,041	0,061
40	0,079	0,04358	0,008	0,094	22222	0,013	0,102	21739	0,0293	3517	0,032	0,048

Notas:

Los datos aquí indicados están sujetos a las tolerancias normales de fabricación y pueden ser modificados sin previo aviso.

(1) La Norma NEMA MW1000 especifica los alambres magneto de capa sencilla para el calibre 14 AWG y menores.

(2) Máxima tensión de embobinado para evitar deformaciones en el alambre, con base en un esfuerzo máximo de 5,98 kgf/mm^2

(3) Capacidad de corriente con base en densidad de corriente para cada clase térmica basada en 0,101 y 0,152 mm^2/A para las clases térmicas de 200°C y 155°C respectivamente.

CENTELSA
CABLES DE ENERGÍA Y DE TELECOMUNICACIONES S.A.

ANEXO 4

CONECTORES PRENSA ESTOPA

Conectores prensa estopa

NYLON CABLE GLAND

Item No.	Mounting Hole	Cable Range
PG-7	12.24mm	3.5-6mm
PG-9	14.76mm	4-8mm
PG-11	18.20mm	5-10mm
PG-13.5	20.36mm	6-12mm
PG-16	22.30mm	10-14mm
PG-21	28.20mm	13-18mm
PG-29	36.24mm	18-25mm
PG-36	46.10mm	22-32mm
PG-42	54.30mm	30-38mm
PG-48	57.70mm	34-44mm

ANEXO 5

CARACTERÍSTICAS DEL CABLE PARA BUJÍA

Cátalogo de Productos

COPPER

Cables para Bujías

Descripción: Conductor de cobre electrolítico, blando, flexible, cableado en haz y aislado con Cloruro de Polivinilo (PVC).

Aplicación: Cable para bujía, se usa para motores de combustión en conexiones entre las bujías, el distribuidor y la bobina. Cercos eléctricos para sistemas de seguridad.

Embalaje: Rollos de 100 metros.

Condiciones: Aislamiento: SAE j 558 a. 1128, UL 62, SAE J 557.2031,Tensión de Servicio: 15 KV,Temperatura de Operación: 80ºC

Norma: ASTM B-3

Segmento: Automotriz **Aislamiento:** PVC

Colores: ■

Código Producto	Calibre AWG	Formación	Diámetro Cordón	Espesor Aislación	Espesor Chaqueta	Diámetro Exterior	Peso Total Kg/Km
13-0001	18	16 x 0.254	1.17	1.6	1.2	6.77	56

Resistencia aislamiento:

ANEXO 6

PROTOCOLO DE PRUEBAS DEL TRANSFORMADOR ELEVADOR

R.V.R. TRANSFORMADORES

CONTAMOS CON REPUESTOS Powell-ESCO (U.S.A.) FOHAMA ARTRANS (ARGENTINA) PARA ECUADOR

Destino	Cliente ALVARO AGUIRRE	Pedido No.	O.T.No. 11051126
Marca	Potencia Nominal 2 KVA	Frecuencia Hz	S/N: 11051126
Normas	Tipo	Clase de Refrigeración	
Clase de Aislamiento	Grupo Conexión	Elev. Temp. °C	Altitud m

	Tensión Nominal	Intensidades	Tensión Serie	Tensión Prueba	BIL
Primario	220 - 240 V	0,8 A	KV	KV	KV
Secundario	2500 V	9,1 A	KV	KV	KV
Datos calculados a 20 °C	WFe W	W Cu W	Io % de In	Uz %	
Datos calculados a 75° C	WFe W	W Cu W	Io % de In	Uz %	
Datos calculados a 75 °C	WFe W	W Cu W	Io % de In	Uz %	

1. Relación de Transformación	Grupo de Conección	Polaridad

Relación de Transformación

Pos. 1				Pos. 2			
Tap	Fase U	Fase V	Fase W	Tap	Fase U	Fase V	Fase W
1	11,363			1	10,416		
2				2			
3				3			
4				4			
5				5			
6				6			

Resistencia de Bobinas Ω

Pos. 1				Pos. 2			
Tap	Fase U	Fase V	Fase W	Tap	Fase U	Fase V	Fase W
1				1			
2				2			
3				3			
4				4			
5				5			
6				6			

2. Resistencia de los Aislamientos	AT Contra BT	AT Contra T	BT Contra T
1000 V	874 G MΩ	768 G MΩ	358 G MΩ

3. Tensión Aplicada				4. Tensión Inducida			
AT Contra BT y T	KV	A	Seg	Tensión	Ix	Iy	Iz
BT Contra AT y T	KV	A	Seg	Frecuencia		Hz	Seg

5. Pérdidas en Vacío	Tensión	Ix	Iy	Iz	Io de in	W Fe
	220 V	0,3 A	A	A	%	32 W
	Watímetro (s)		Constante (s)			

6. Pérdida de Corto - Circuito				
	I de AT 0,8 A	Vcc 119 °C V	Ix	AIU A
	I de BT A	Uz °C 4,8 %	Iy	AIV A
	Posición Conmutador	W Cu 82 W	Iz	AIW A
	Watímetro (s)	Constante (s)		

7. Resistencia Entre Bornos			
	AT UV 51,4 Ω	UV Ω	WU Ω
	BT XY 0,480 Ω	YZ 0,524 Ω	ZX Ω
Temperatura Ambiente °C	I²R W	Ur %	Ux % Wa %
Datos a 75 °C	I²R W	Ur %	Uz % Wa %
			W Cu W

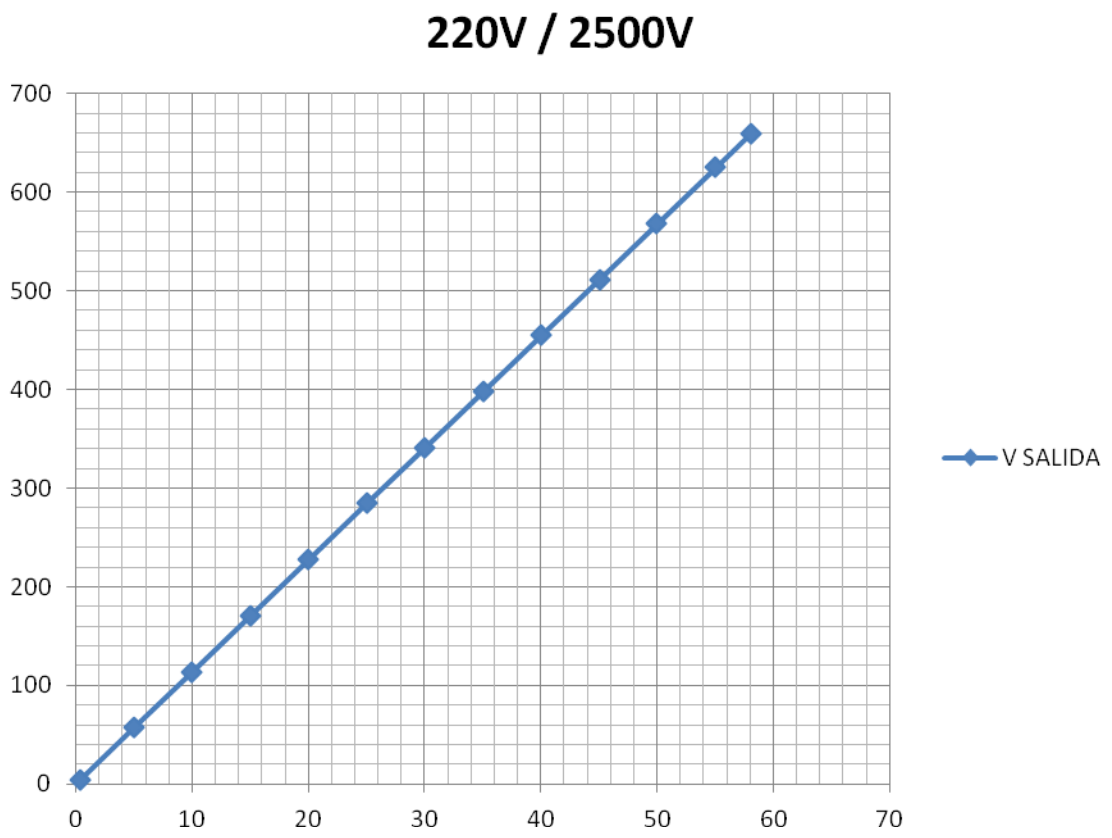
8. Rigidez Dieléctrica del Aceite	Número de Pruebas	Promedio	Rigidez
		kV/2,5mm	kV/cm

R..lizado Por	V° B°
Fecha	Quito - Ecuador

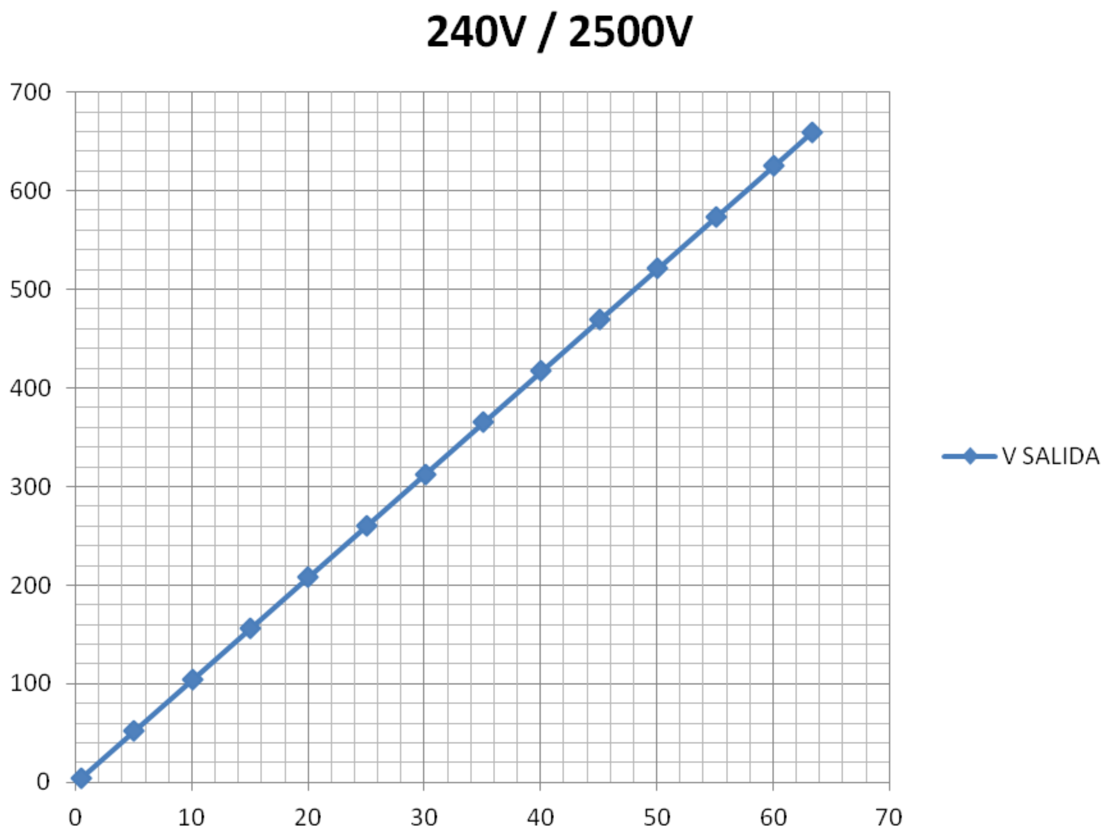
ANEXO 7

TABULACIÓN DE MEDICIONES AL TRANSFORMADOR ELEVADOR Y REPRESENTACIÓN EN GRÁFICAS

220 V	
ENTRADA	**SALIDA**
0,397	4,246
5,002	57,1
10,01	113,6
15,03	170,7
20,00	227,2
25,02	284,7
30,02	340,9
35,03	397,9
40,03	454,8
45,04	511,7
49,97	567,7
55,05	625,3
58,04	659,6



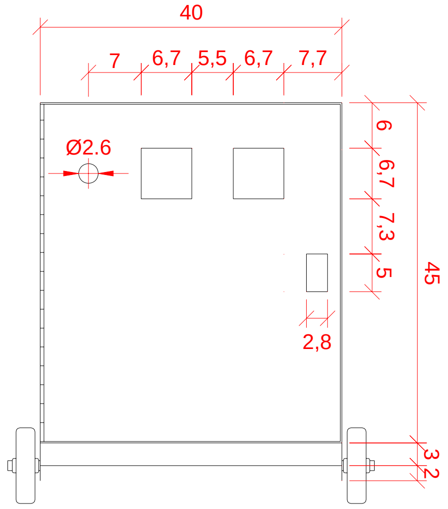
240 V	
ENTRADA	SALIDA
0,443	4,397
5,023	52,26
10,06	104,6
15,06	156,7
20,01	208,3
25,07	260,9
30,06	312,9
35,07	365,1
40,07	417,3
45,04	469,1
50,05	521,2
55,06	573,4
60,03	625,2
63,35	659,9



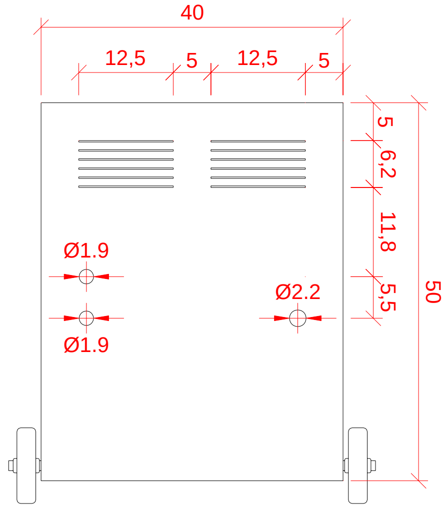
ANEXO 8

PLANOS DE CONSTRUCCIÓN DEL GABINETE DE LA FUENTE DE PODER

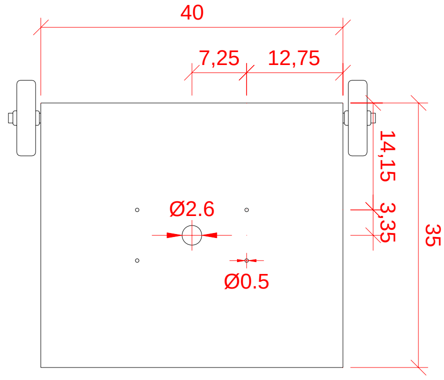
VISTA FRONTAL



VISTA POSTERIOR



VISTA SUPERIOR



UNIVERSIDAD TECNOLÓGICA EQUINOCCIAL		
Proyecto: Planos Gabinete de Fuente	**PLANOS GABINETE DE FUENTE**	**Fecha:** Febrero - 2012
Dibujó: Alvaro Aguirre Granda		**Escala:** 1 : 100
Aprobó: Ing. Ricardo Aguirre		**Lámina Nº:** 1 de 1