ESCUELA SUPERIOR POLITECNICA DEL LITORAL

Facultad de Ingeniería en Mecánica y Ciencias de la Producción.

"Alisado De Chapas De Acero Al Carbono En Una Compañía Metal Mecánica"

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DEDICATORIA

A Dios, por haberme dado la vida y las condiciones para estudiar.

A mis padres, porque nunca dejaron de alentarme para terminar la carrera y obtener este título.

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(Reglamento de Graduación de la ESPOL)

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RESUMEN

La empresa donde realizo mi trabajo profesional tiene como actividad la importación de rollos de acero laminado bajo especificaciones ASTM, de diferentes partes del mundo y en la planta nos encargamos de hacerla lisa o plana, cortarla a 1220mm x 2440mm, ponerla a escuadra y entregarla empacada a nuestros clientes con las que desarrollan su actividad productiva haciendo toda clase de productos en acero.

En la presente tesis de grado se exponen las acciones de transformación que se realizaron en esta empresa a fin de acometer con tres problemas que tenían en situación crítica los índices empresariales. Estos eran relacionados con: la capacidad de producción, la calidad del producto y el índice de maquila.

Se mejoró el coeficiente de maquila en un 52,17%, se incremento la capacidad de producción en un 100% y se disminuyo la cantidad de planchas que no cumplió con especificación de medidas y cuadratura en un 90%.

Se requirieron adecuar máquinas, adquirir otras y hacer uso de la metodología de tiempos y movimientos para cambiar la operación de la línea, pero el resultado fue sorprendente y de éxito. Ahora se planea entrar en fase de automatización y ventas al exterior.

ÍNDICE GENERAL

ABREVIATURAS

TM	Toneladas métrica
Kg.	Kilogramos
ASTM	American Society Testing Materials
mm	Milímetros
N	Newton
mm2	Milímetros cuadrados

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INTRODUCCION

Existen dos maneras de tener materia prima en forma de lámina para realizar trabajos rutinarios de calderería, la una es importarlas directamente en forma de paquetes para luego comercializarlas al precio de referencia del mercado obteniéndose con esto algún margen de ganancia y la otra es importar la materia prima llamada “bobina” y mediante un proceso de conversión denominado “alisado” producirlas, para luego comercializarlas al mismo precio de referencia anterior, siendo esta forma la que mayor margen de ganancia se obtiene ya que el costo por tonelada métrica de la materia prima más los costos de conversión llamados “coeficiente de maquila” de las chapas es menor que el precio por tonelada métrica de los paquetes de chapas importadas.

Todas la compañías dedicadas a la misma actividad que operan en el Ecuador tienen fijado un valor común estándar de coeficiente de maquila, para que el proceso de alisado se considere rentable y es fundamental para cualquier de estas compañías mantenerlo o mejor aun bajarlo, de lo contrario podría suceder que el proceso se convierta en no rentable, ya que el precio por tonelada de la materia prima más los costos de conversión serían mayores que de los paquetes importados.

La presente tesis de grado tiene como objetivo general, mejorar la eficiencia de la línea de alisado de chapas de acero al carbono laminadas en frío para conseguir un coeficiente de maquila ajustado a los valores esperado por la Gerencia y que son del orden de $40 TM.

A fin de cumplir con este objetivo se han planteado varios objetivos específicos que ayudan a cumplir de varias formas a transformar las falencias detectadas en la producción.

En primer lugar, esperamos disminuir el porcentaje de chapas producidas que no cumplen con el estándar de calidad establecido por la norma de referencia y de esta manera aumentar la confianza del consumidor final que tendrá siempre un producto de primera calidad, como segunda acción se acometerá el objetivo de mejorar la capacidad de producción de chapas alisadas para bajar el valor de coeficiente de maquila consiguiendo que la línea de proceso se sitúe al mismo nivel de competitividad que las demás empresas afines.

Al comienzo de la modificación de la línea, el 12 % de chapas producidas mensualmente, no cumplen con el control de calidad establecido, ocasionando que los consumidores finales de estas chapas no las acepten como de primera calidad, siendo devueltas o exigiendo que el precio de venta de las mismas sea reducido a un valor menor que el establecido por el mercado, ya que las consideran como chapas de segunda calidad, aprovechándose de esta situación para afirmar que toda la producción también es de segunda y así sacar provecho para obtener un menor precio de venta. Por otro lado, la cantidad de las chapas producidas mensualmente no eran suficientes para obtener un valor de coeficiente de maquila que este de acuerdo al estándar establecido, valor necesario para que la línea de proceso se considere rentable, no pudiendo competir contra plantas similares.

Finalmente, también se acometió el problema de las condiciones de trabajo del personal que labora en esta línea tenía una tarea agotadora y de poca eficiencia luego de los mejoras y después de un entrenamiento se convirtió en una de las más eficiente de la compañía.

CAPITULO 1

1. EL PROCESO DE ALISADO

El proceso de alisado es el proceso por el cual se convierte mediante deformación plástica una chapa arrollada llamada "bobina" en otra completamente plana.

La bobina es necesario desenrollarla, enderezarla con una planitud que permita su utilización y cortarla transversalmente para obtener chapas al largo de 2440 mm que es la medida comercial establecida. La línea de proceso que realiza esta operación se llama "máquina alisadora" y lleva normalmente incorporado el elemento desenrrollador, el enderezador y la guillotina transversal.

Las bobinas son importadas de diversas usinas de América, Europa y Asia solicitadas en ancho de 1220 mm, con calidad del acero que las conforman de acuerdo a la norma ASTM A1008/A1008M , los espesores son los utilizados comercialmente en nuestro medio para estas chapas, es decir 0.50,0.60,0.70, 0.75, 0.80, 0.90, 1.1 mm. Los pesos de estas bobinas fluctúan entre 5.000 y 6.800 Kg.

FIGURA 1.1 MATERIA PRIMA (BOBINA)

FIGURA 1.2 ESQUEMA SOBRE EL PROCESO DE CONVERSIÓN

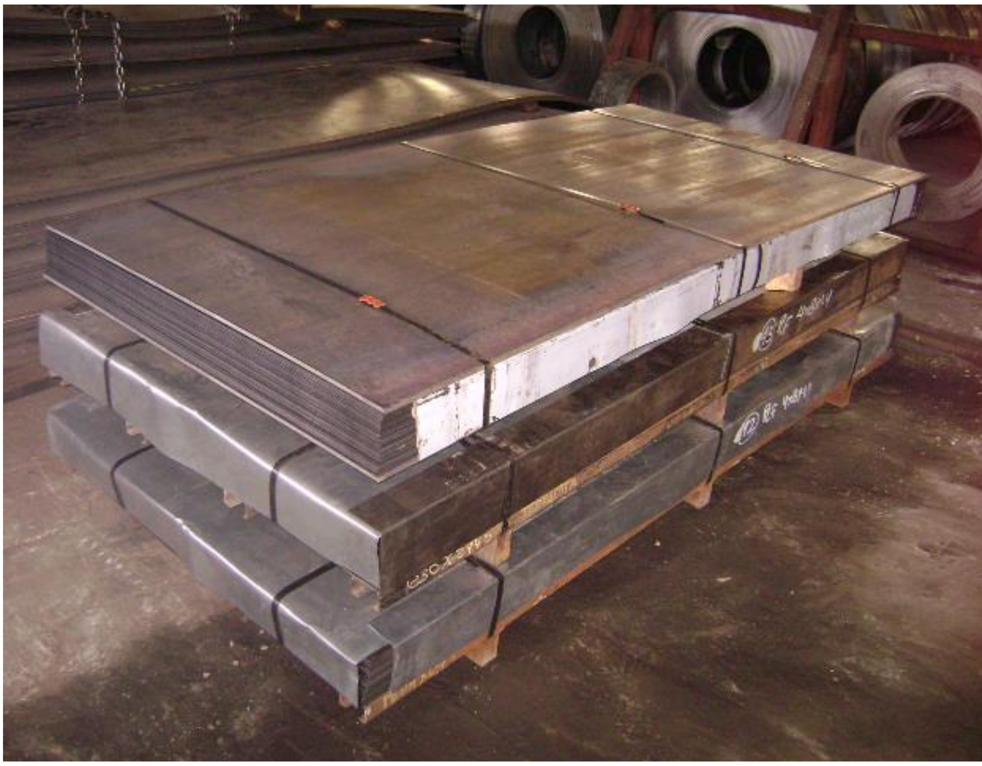

FIGURA 1.3 PRODUCTO TERMINADO (CHAPAS ALISADAS EN PAQUETE)

1.1 La máquina alisadora y los parámetros que gobiernan el proceso de alisado.

La máquina alisadora es la línea de proceso donde se alisan las chapas, esta compuesta por un conjunto de elementos que realizan durante el proceso de alisado el trabajo de desenrollar las bobinas, alisar las chapas que se desenrollan, cortar transversalmente las chapas alisadas, extraer y acumular las chapas cortadas.

Los elementos que conforman la máquina alisadora son: el desenrrollador, el planchador, el cortador y la mesa de salida.

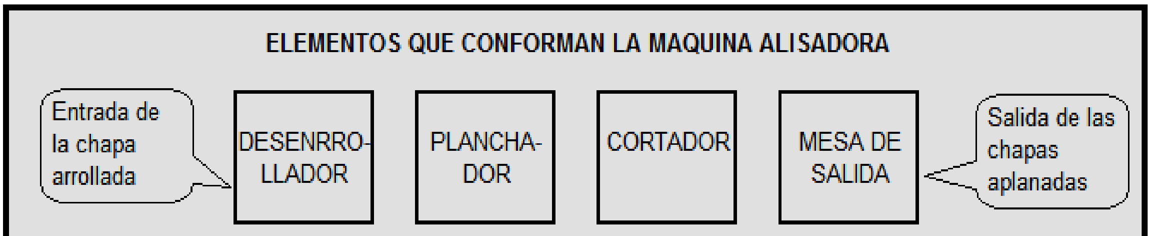

FIGURA 1.4 ELEMENTOS QUE CONFORMAN LA MAQUINA ALIZADORA

El Desenrrollador.- Llamado también "portabobina", es el elemento de la máquina alisadora en el cual se montan las bobinas para que se desenrollen paulatinamente a medida que ocurre el proceso de alisado, básicamente es un soporte giratorio para la bobina y a la vez rota conjuntamente con ella durante el proceso. Existen algunos tipos de desenrrolladores pero los más utilizados son los denominados de “Conos dobles” y de “Mandril expansible”

FIGURA 1.5 DESENRROLLADOR DEL TIPO CONO DOBLE

FIGURA 1.6 DESENRROLLADOR DEL TIPO MANDRIL EXPANDIBLE

El Planchador.- Es el elemento de la máquina alisadora que aplana por deformación plástica las chapas de acero durante el desenrrollamiento de la bobina.

Este elemento está compuesto de dos hileras de rodillos denominado "tren de rodillos planchadores" fabricados en acero de 80 a 85 N/mm2 de resistencia de diámetro 120 mm y de longitud 2140 mm dispuestos en zigzag, en número de 8 inferiores y 9 superiores.

La hilera de rodillos inferiores es la que normalmente se acciona mediante un motor eléctrico, mientras que la hilera de rodillos superiores es móvil en sentido vertical para permitir la regulación de la presión de deformación que se aplicará a la chapa.

A la entrada y salida del planchador se encuentran sendas

mesas metálicas destinadas a sostener la chapa a enderezar

FIGURA 1.7 VISTA A LA ENTRADA DEL PLANCHADOR

FIGURA 1.8 VISTA LATERAL DEL PLANCHADOR

El Cortador.- Es el elemento de la máquina alisadora que produce el corte transversal a la chapa previamente aplanada en el tren de rodillos alisadores cuando esta ha alcanzado la longitud comercial establecida, básicamente es una cizalla tipo guillotina.

FIGURA 1.9 EL CORTADOR

La Mesa de Salida.- Es el elemento de la máquina alisadora que conduce las chapas cortadas desde la salida del cortador hasta el lugar de apilamiento de la misma.

Esta mesa está compuesta de una estructura con rodillos motorizados de ancho y largo adecuado para que las chapas alisadas puedan ser transportadas sin ningún inconveniente

FIGURA 1.10 MESA DE SALIDA

Parámetros que gobiernan el proceso de alisado.- Los parámetros que gobiernan el proceso de alisado son: el espesor de la chapa de la que está formada la bobina, el peso de esta y el largo al que se corta las chapas.

El espesor define la calibración del tren de rodillos planchadores y la abertura de separación de las cuchillas del cortador.

El peso de la bobina y el largo de las chapas cortadas, determinan el tiempo requerido para procesarla así como los equipos utilizados en el apilado, empaquetamiento y evacuación de los paquetes del área de trabajo.

1.2 La norma ASTM A1008/A1008M para bobinas de acero al carbono laminadas al frío

La norma que especifica la calidad del acero del que está compuesta la bobina es la norma ASTM A1008/A1008M, esta se refiere a la especificación estándar del acero al carbono que conforma la bobina laminada en frío en los tipos de acero calidad comercial, acero estructural de alta-resistencia y baja aleación, acero de alta-resistencia y baja aleación con mejoras para la conformabilidad.

Esta norma clasifica al acero al carbono laminados en frío que conforma las chapas con las siguientes designaciones:

Comercial Steel (CS Types A, B, and C)

Acero calidad comercial (Tipos A, B, y C)

Drawing Steel (DS Types A and B)

Acero para embutición moderada (Tipos A y B)

Deep Drawing Steel (DDS)

Acero para embutición profunda

Extra Deep Drawing Steel (EDDS)

Acero para embutición extra profunda

Structural Steel (SS grades 25, 30, 33 Types 1 and 2, 40 Types 1 and 2, and 80)

Acero calidad estructural (grados 25,30, 33 tipos 1 y 2, 40 tipos 1 y 2, y 80)

High-Strength Low-Alloy Steel (HSLAS grades 45, 50, 55, 60, 65 and 70 in classes 1 and 2)

Acero de alta resistencia y baja aleación (grados 45, 50, 55, 60, 65 y 70 in clases 1 y 2)

High-Strength Low-Alloy Steel with Improved Formability (HSLAS-F grades 50, 60, 70, and 80)

Acero de alta resistencia y baja aleación con mejoras para la conformidad (grados 50, 60, 70, y 80)

Las bobinas que esta compañía importa son en acero calidad comercial CS tipos A, B y C cuyas composiciones químicas son las siguientes:

TABLA 1

COMPOSICIÓN QUIMICA DE LOS ACEROS CALIDAD COMERCIAL (CS)

ACERO CS	% C	% Mn	% P	% S	Al	Si	Cu	Ni	Cr	Mo	V	Cb	Ti	N
Tipo A	0,10	0,60	0,03	0,035	-----	-----	0,20	0,20	0,15	0,06	0,008	0,008	0,008	-----
Tipo B	0,02 -0,15	0,60	0,03	0,035	-----	-----	0,20	0,20	0,15	0,06	0,008	0,008	0,008	-----
Tipo C	0,08	0,60	0,10	0,035	-----	-----	0,20	0,20	0,15	0,06	0,008	0,008	0,008	-----

Para estos tipos de aceros la norma no especifica el porcentaje de silicio, aluminio ni nitrógeno.

Las propiedades mecánicas de los acero CS tipo A, B y C son:

Esfuerzo de fluencia 140 a 275 MPa

Elongación en 50 mm mayor o igual a 30%

La norma no especifica el esfuerzo de tensión para estos aceros. Esta gama de aceros es ampliamente utilizada en aplicaciones de plegado y embutición de los sectores de industria general, edificación y automóvil, así como en sectores relacionados a éstos.

1.3 La norma ASTM A568/A568M aplicada como control de calidad de las chapas alisadas.

La norma ASTM A568/A568M es la norma tomada como referencia y utilizada para controlar la calidad de las chapas obtenidas, en cuanto a las tolerancias de las medidas y acabado se refiere exigido para los estándares comerciales establecidos.

En esta compañía también se aplican procedimientos propios de controles en cuanto a la observación física de los productos que se manejan con el propósito de evitar que el producto final se despache con imperfecciones, este control es aplicados desde que se recibe la materia prima hasta que el producto terminado es despachado, queriendo decir con esto que tanto la bobina, las chapas durante el proceso de alisado y la conformación de los paquetes de chapas son inspeccionadas y registradas sus resultados para futuros análisis de procesos.

Controles de calidad aplicados a la materia prima.

Siendo las bobinas la materia prima de donde se obtienen las chapas, es muy importante verificar visualmente y realizar mediciones específicas a ellas para comprobar que están aptas para de estas obtener el correspondiente producto final. Son dos las actividades de control que se le realizan a las bobinas, una es la inspección visual y la otra son las mediciones tomadas.

Sobre la inspección visual podemos decir que al momento de recepcionar las bobinas recibidas de importación o compradas localmente, se realiza una inspección para determinar el estado físico de las mismas, esta inspección corresponde a la búsqueda de abolladuras, oxidaciones, aplastamiento, y a la comprobación de las especificaciones técnicas indicadas en la etiqueta de identificación comparadas con la guía de importación o la factura correspondiente.

Si alguna bobina recibida presenta oxidación o abolladuras se notifica a la Gerencia para que esta realice los respectivos reclamos al proveedor de la materia prima, originándose dos situaciones, una es la devolución de la misma y la otra es el consecuente proceso.

En la etapa de preparación de la bobina antes del proceso de alisado, se toman mediciones en cuanto al peso, espesor de la chapa, y el ancho de estas.

Todos los datos obtenidos de las operaciones de control descritas anteriormente son registrados en los correspondientes documentos destinados para estos fines, indicando que las inspecciones visuales pertenecen al control interno de esta compañía y las tolerancias en las mediciones obtenidas son comparadas con las tolerancias indicadas en la norma de control establecida.

A continuación se presentan algunos casos de daños ocurridos en las bobinas.

FIGURA 1.11 BOBINA APLASTADA

FIGURA 1.12 BOBINA CON FORRO DAÑADO

FIGURA 1.13 BOBINA GOLPEADA

FIGURA 1.14 PROTECCIÓN DE BOBINA DAÑADA

Controles aplicados a las chapas durante el proceso de alisado.

Son realizados los respectivos controles visuales y mediciones a las chapas durante el proceso de alisado, esto es con el fin de evitar que posteriormente se formen los paquetes con chapas defectuosas.

La inspección visual se utiliza para comprobar que las chapas durante el proceso de alisado no se obtengan con defectos tales como, abolladuras, falta de planitud (ondulaciones), bordes dañados, rebabado en el corte transversal producido por las cuchillas del cortador

Periódicamente cada cierta cantidad de chapas producidas se toman mediciones tales como el espesor, el ancho, el largo y el escuadrado de las chapas, con la finalidad de verificar que el proceso continúa realizándose de acuerdo a lo planificado, de lo contrario se efectúan los correctivos adecuados.

Medición del espesor de la chapa.- La tolerancia en el espesor según la norma adoptada como referencia debe ser (+ -) el 10 % del espesor nominal de la chapa, pero como la bobina es comprada el espesor viene indicado en la etiqueta de identificación, de igual forma el espesor de las chapas es medido para su comprobación con lo indicado por el fabricante.

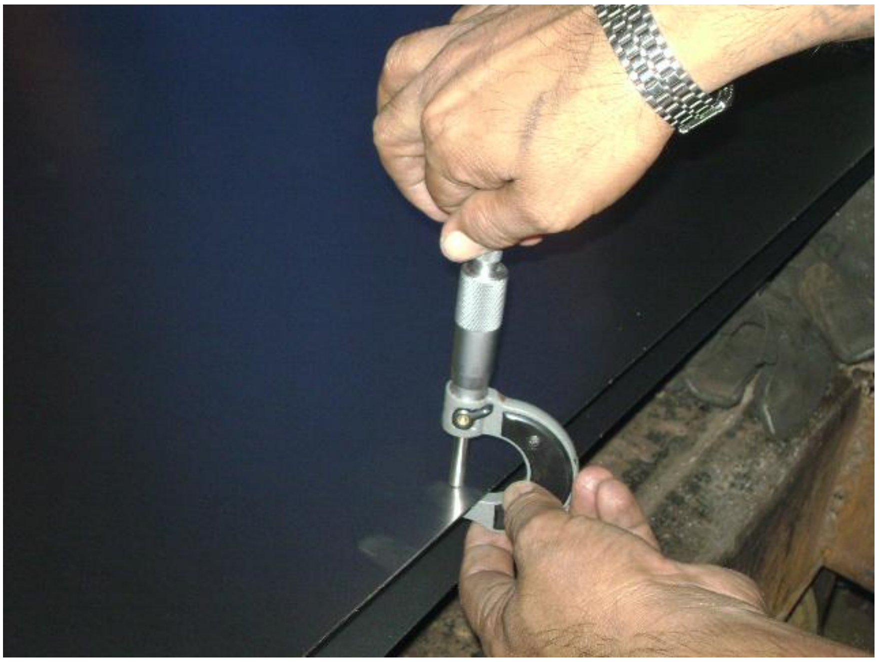

FIGURA 1.15 MEDICIÓN DEL ESPESOR DE LA CHAPA

Medición del ancho de la chapa.- La tolerancia en la medida del ancho según la norma de calidad adoptada como referencia debe ser (+ -) el 1 % del ancho comercial nominal de la chapa, el mismo que es 1.220 mm es decir cualquier chapa medido su ancho debe estar entre 1.208 a 1.232 mm.

La chapa indicada en la figura mide 1.222 mm de ancho y según la tolerancia tiene el ancho comercialmente establecido.

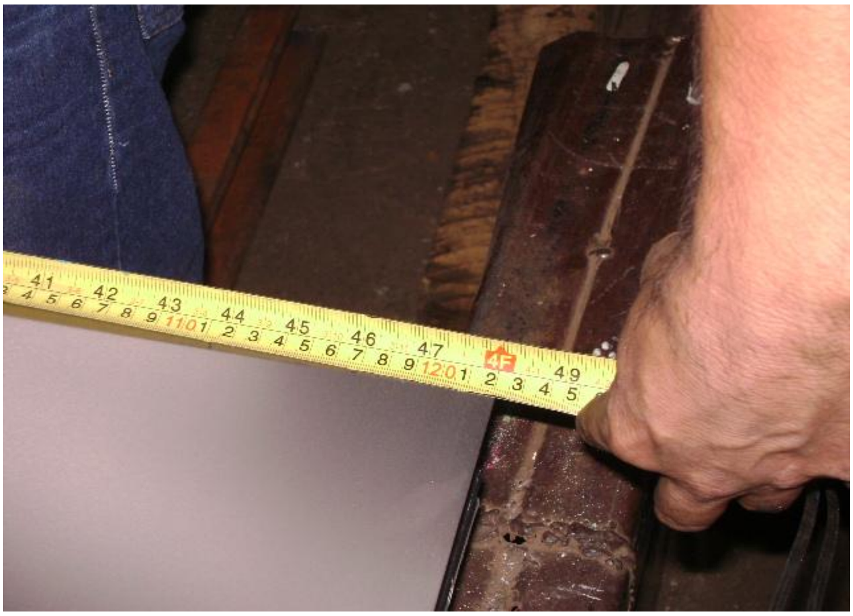

FIGURA 1.16 MEDICIÓN DEL ANCHO DE LA CHAPA

Medición del largo de la chapa.- La tolerancia en el largo según la norma adoptada como referencia puede llegar hasta (+) 15 mm como máximo del largo comercial establecido siendo este 2.440 mm, por tanto la longitud a la cual se cortó la chapa mostrada en la figura (2.443 mm) cumple con la tolerancia.

FIGURA 1.17 MEDICIÓN DEL LARGO DE LA CHAPA.

Medición del escuadrado de la chapa.- La falta de escuadrado admisible según la tolerancia indicada en la norma de control deberá ser menor o igual a 1.6 mm; también se obtiene midiendo las diagonales donde la diferencia entre ellas debe ser menor o igual a 2.86 mm.

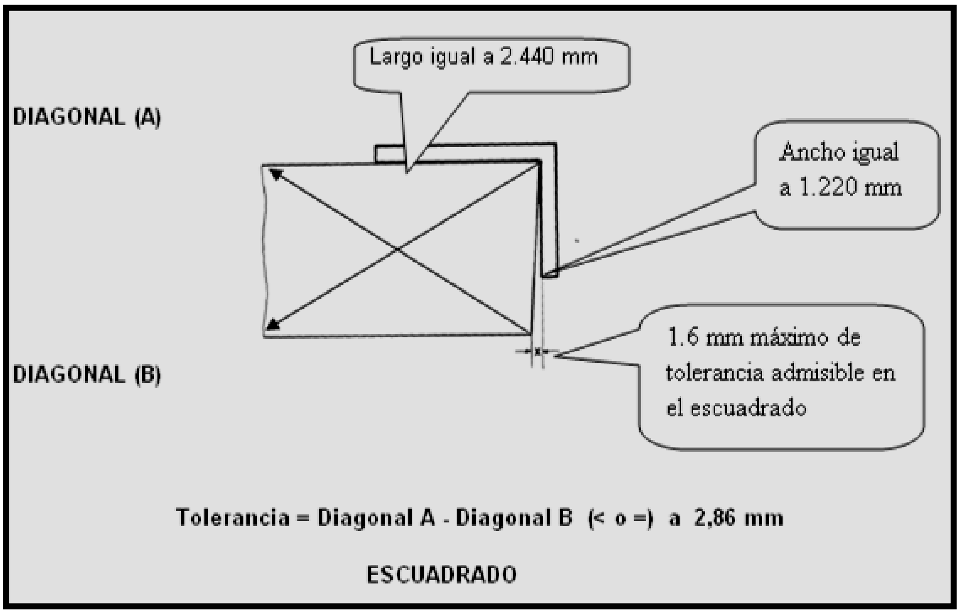

FIGURA 1.18 ESCUADRADO

FIGURA 1.19 MEDIDA DE DIAGONAL (B)

IGUAL A 2.724 MM

FIGURA 1.20 MEDIDA DE DIAGONAL (A)

IGUAL A 2.733 MM

Si 1.6 mm de escuadrado corresponde a 2.86 mm en la diferencia entre diagonales (A – B), entonces la chapa mostrada no cumple con la tolerancia, puesto que al restar 2.733 mm correspondiente a la diagonal mayor menos 2.724 mm correspondiente a la diagonal menor el resultado es 9 mm siendo este valor superior al establecido como control.

<u>Controles aplicados a los paquetes de chapas producidas.</u>

Este tipo de control es netamente visual y en él se verifica que los paquetes formados salgan perfectamente embalados, enzunchados y con la etiqueta de identificación correctamente explicita, cabe indicar que en esta etapa se verifica por última vez la cantidad de chapas que contienen el paquete

Defectos en las chapas obtenidas que originan que estas no cumplan con la tolerancia indicada en el control de calidad establecido.

Los defectos en las chapas alisadas originados durante el proceso de alisado, son las causas para que el 12% de la producción mensual no cumplan con los estándares de calidad establecido, considerándolas por este motivo como de segunda calidad, siendo estos defectos las ondulaciones superficiales, la rebaba en el borde cortado, los bordes ondulados o rotos y los bordes descuadrados.

Chapas con ondulaciones superficiales.- Este defecto es producto de la calibración incorrecta del tren de rodillos del planchador, por lo general resulta en la primera chapa obtenida ya que es la que se utiliza para comprobar la calibración antes realizada.

FIGURA 1.21 CHAPAS CON ONDULACIONES SUPERFICIALES

Chapas con rebaba en el borde cortado.- Este defecto se produce en las primeras chapas procesadas y se debe a la incorrecta calibración de las cuchillas del cortador.

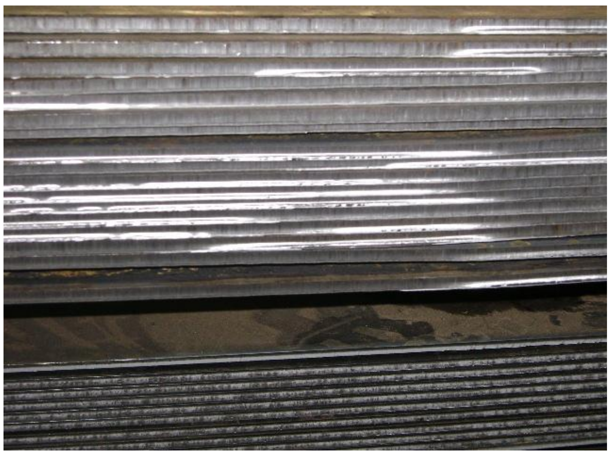

FIGURA 1.22 CHAPAS CON REBABA EN EL BORDE CORTADO

Chapas con los bordes ondulados y rotos.- Este defecto se debe al daño producido por los conos del desenrrollador sobre la bobina al momento de enhebrarla.

En la operación de enhebrado el desenrrollador de esta máquina que es del tipo cono doble, daña el interior de la bobina provocando que las últimas vueltas que se desenrollan se dañen, obteniéndose como resultado chapas alisadas con los filos totalmente ondulados y en algunos casos rotos.

FIGURA 1.23 CHAPAS CON BORDES ONDULADOS

Chapas con descuadre.- Este defecto se produce cuando la chapa se desalinea de la posición correcta que debe mantener cuando esta pasa por el planchador. Otra causa de descuadre pero en menos grado es cuando la chapa se desplaza ligeramente al momento del corte empujada por las cuchillas del cortador.

Chapas oxidadas y abolladas.- Estos defectos ocurren cuando la materia prima presenta oxidaciones o golpes.

Las producciones obtenidas de estas bobinas son consideradas como chatarra o de segunda calidad dependiendo del estado de deterioro del producto obtenido y no son registradas dentro del total producido en ese mes.

FIGURA 1.24 CHAPA OXIDADA

FIGURA 1.25 CHAPA ABOLLADA O ROTA

Los valores porcentuales de cada tipo de defectos que conforman el 12% antes mencionado en el año 2007 se indican en el siguiente cuadro:

TABLA 2

PORCENTAJE DE DEFECTOS GENERADOS EN LAS CHAPAS DURANTE EL PROCESO PRODUCTIVO

TIPOS DE DEFECTOS	Año 2007												Promedio año
	ene	feb	mar	abr	may	jun	jul	ago	sep	oct	nov	dic	
	PORCENTAJE												
Chapas descuadradas	6,0	7,0	6,0	5,0	6,0	5,0	6,0	5,0	6,0	5,0	7,0	6,0	**5,8**
Chapas con ondulaciones	0,5	0,4	0,5	0,5	0,5	0,5	0,5	0,8	0,8	0,8	1,0	1,0	**0,7**
Chapas con bordes con rebaba	1,0	0,0	0,0	0,0	0,5	0,5	0,0	0,0	0,0	0,0	0,5	0,5	**0,3**
Chapas con bordes rotos	5,0	5,0	5,0	5,0	5,5	5,5	5,5	6,0	6,0	6,0	6,0	6,0	**5,5**
PORCENTAJES TOTALES	**12,5**	**12,4**	**11,5**	**10,5**	**12,5**	**11,5**	**12,0**	**11,8**	**12,8**	**11,8**	**14,5**	**13,5**	**12,3**

Por lo tanto disminuir el valor de estos porcentajes era uno de los mayores problemas a resolver. Es muy importante priorizar los alcances de realizar un buen control de calidad ya que si por algún error alguna chapa con defecto es considerada como de primera calidad, al momento de comercializarla el consumidor final la detectará, y podría rechazar todo el lote fabricado o lo que es peor se aprovecharía de la situación para pedir que el precio de venta de todo el lote sea rebajado.

Conseguir que el consumidor final mantenga la confianza que el producto entregado es de primera calidad, también era otro problema que debía ser resuelto.

1.4 El coeficiente de maquila establecido como índice de eficiencia de la línea de producción

El coeficiente de maquila establecido como índice de eficiencia de la línea de alisado, es el valor correspondiente al coeficiente costo / beneficio, donde el costo es medido en dólares y corresponde a los recursos gastados para transformar la bobina en chapas alisadas, y el beneficios corresponde a la producción misma de las chapas medido en toneladas métricas, tanto los valores de costo como beneficio son datos registrados mensualmente.

El valor mensual de referencia correspondiente al coeficiente de maquila establecido por la Gerencia de esta compañía para que su línea de proceso se considere rentable es 40 dólares la tonelada métrica, esta cifra establecida es un valor común para todas las demás líneas de producción de las compañías dedicadas a la misma actividad productiva que operan en el País. Los componentes del costo son definidos por la administración de esta compañía como "Gastos directos" y corresponde a los siguientes rubros:

Servicio prestado tercerizados

Gastos comisión tercerizados

Gastos comisión servicios

Seguro maquinaria

Seguro accidentes personales

Seguro incendio

Seguro lucro cesante por maquinaria

Arriendo maquinaria

Honorarios profesionales

Suministros y repuestos

Los datos registrados durante el año 2007, referente a los costos generados para convertir bobinas en chapas alisadas, así como los de las producciones obtenidas y los valores de coeficiente de maquila causados, se indican en la tabla siguiente:

TABLA 3

VALORES DE PRODUCCIONES, COSTOS GENERADOS Y COEFICIENTES DE MAQUILA OBTENIDOS DURANTE EL AÑO 2007

	ene	feb	mar	abr	may	jun	jul	ago	sep	oct	nov	dic	Promedio año
Producciones (TM)	112	116	100	112	115	112	118	115	110	112	112	114	112
Costos ($)	4.800	4.800	4.850	4.800	4.500	4.500	4.800	4.800	4.500	4.500	4.800	4.800	4.704
Coeficiente de maquila ($ / TM)	42,86	41,38	48,50	42,86	39,13	40,18	40,68	41,74	40,91	40,18	42,86	42,11	41,88

Según los datos estadísticos el valor promedio para el coeficiente de maquila registrado en el año 2007 fue 41.88 dólares la tonelada métrica, siendo este valor mayor que el establecido por la administración de la compañía.

Por diversos factores comerciales esta línea de transformación operó en estas condiciones hasta Diciembre del mismo año, y a partir de Enero del año en curso se aplicaron los correctivos y mejoras propuestas.

Analizando los altos valores registrados de coeficiente de maquila tenemos que son el resultado de las bajas producciones obtenidas en esta línea de proceso, por lo tanto aumentar la producción de chapas para hacer a esta línea competitiva y eficiente era otro problema que se debía solucionar.

1.5 Descripción del proceso de alisado de la línea de producción en referencia.

Los eventos sucesivos que conformaban el proceso de alisado antes de las mejoras aplicadas detallan todas las operaciones que se ejecutaban para convertir una bobina en paquetes de chapas alisadas, estos eventos eran los siguientes:

Recepción de la orden de trabajo.
Solicitud de la bobina en la bodega de materia prima.
Preparación de la bobina.
Calibración del tren planchador.
Calibración de las cuchillas del cortador.
Enhebrada de la bobina.
Planchado de las chapas.
Reajustes por desalineamiento de la chapa.
Apilamiento de las chapas.
Conformación de los paquetes de las chapas

Evacuación de los paquetes de chapas

En el diagrama de flujo mostrado a continuación se describe con más detalle los eventos referidos anteriormente:

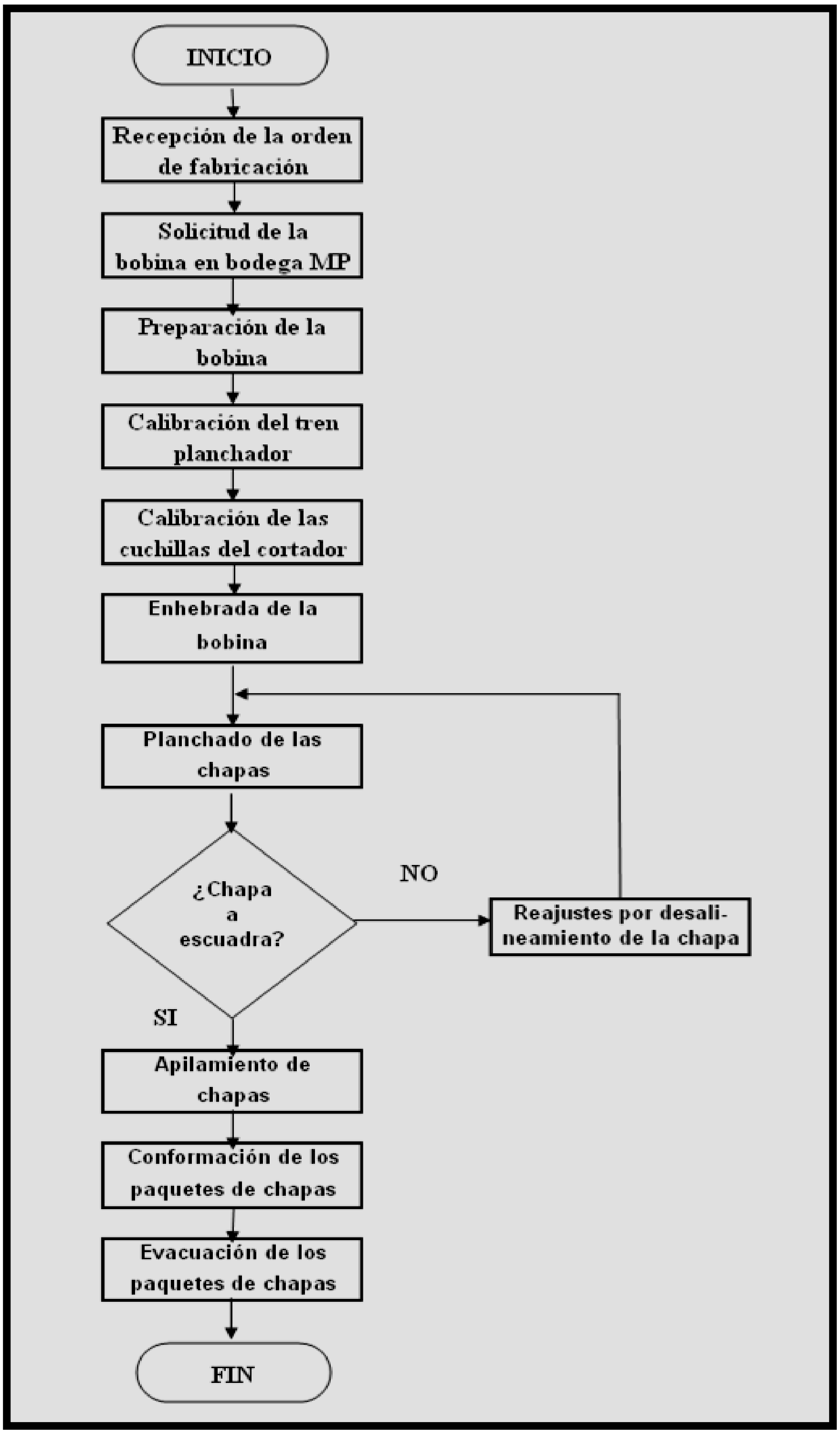

FIGURA 1.26 DIAGRAMA DE FLUJO DEL PROCESO DE ALISADO ANTES DE LAS MEJORAS REALIZADAS

Recepción de la orden de fabricación.- Es el momento en que el operador de la máquina alisadora recibe de manos del supervisor de Planta la orden de trabajo, en esta orden se detalla las características de la bobina a procesarse y lo que se requiere obtener de ella.

Solicitud de la bobina en la bodega de materia prima.- En este evento, el operador de la máquina alisadora solicita al bodeguero de materia prima y a la vez operador del equipo de carga y transporte de bobinas denominado "Puente grúa de 27

T" que extraiga de la zona de materia prima la bobina requerida y la ubique en la zona de preparación de la misma.

Preparación de la bobina.- La bobina ubicada en la zona de preparación se le extrae la envoltura de protección que la cubre, se la pesa en una balanza electrónica y se anota en la orden de trabajo todos los datos indicados en la etiqueta de importación y el peso registrado.

FIGURA 1.27 ELIMINACIÓN DEL FORRO PROTECTOR

FIGURA 1.28 PESAJE EN BALANZA ELECTRÓNICA

Calibración del tren de rodillos superiores del planchador.- Terminada la preparación de la bobina, el operador de la máquina alisadora, calibra el tren de rodillos superiores del planchador de acuerdo al espesor de la chapa que se alisará con el propósito de ajustar la presión necesaria para que las chapas obtenidas estén completamente planas.

Calibración de la abertura entre cuchillas del cortador.- Después de calibrar el planchador, el operador continúa con la calibración de las cuchillas del cortador de acuerdo también al espesor de chapa a cortar, para obtener chapas perfectamente cortadas y sin rebabas, por criterio técnico la luz que se da a las cuchillas es del 10% del espesor de chapa.

Enhebrada de la bobina.- Enhebrar la bobina abarca algunos pasos; montar la bobina en el desenrrollador de la máquina, tomar el inicio o punta de la chapa de la bobina e introducirla entre los rodillos del planchador, inmediatamente se da marcha a la máquina en modo paso a paso para que la chapa avance lentamente por todos los rodillos desde la entrada hasta la salida del planchador hasta llegar al cortador, aquí se corta el comienzo de la chapa para eliminar esta parte que generalmente sufre daño debido al manipuleo de la bobina y dar el escuadrado inicial.

FIGURA 1.29 BOBINA EN FASE DE MONTAJE EN DESENRROLLADOR

Planchado de las chapas.- Se acciona la máquina en modo normal y se inicia el proceso de planchado, cuando la chapa alisada antes de ser cortada alcanza el largo establecido, acciona un limitador de carrera tipo bandera produciéndose que el motor del planchador se detenga y se produzca al mismo tiempo el corte transversal respectivo, después del corte, la cuchilla superior del cortador regresa a la posición superior original activando el motor de la mesa de salida que da movimiento a los rodillos transportadores de esta provocándose el arrastre de la chapa cortada desde la salida del cortador hasta el lugar de apilamiento que está en el piso al final de la mesa de salida.

FIGURA 1.30 CHAPA EN FASE DE PLANCHADO

Reajustes por desalineamiento de la chapa.- Periódicamente es detenido el proceso para comprobar que la calidad de las chapas alisadas estén de acuerdo a los controles de calidad establecidos, si las chapas obtenidas no cumplen con los estándares, se realizan los correctivos pertinentes.

El procedimiento para corregir el descuadre de las chapas es levantar el tren planchador y alinear la posición de la chapa con respecto a la posición de la bobina montada en el desenrrollador y a la vez con respecto a la perpendicularidad de la cuchilla del cortador, una vez hecho esto se baja el tren planchador y se continua con el proceso de alisado hasta que la bobina se haya desenrrollado completamente.

El planchador de esta máquina al no tener un dispositivo que guiará la chapa a la entrada del tren aplanador provoca un desalineamiento de la chapa que conforma la bobina montada en el desenrrollador con respecto al tren de rodillos alisadores, obteniéndose como resultado en las chapas un descuadre severo, que a su vez originaba la paralización del proceso por lapsos considerables de tiempo hasta que se hacían las respectivas correcciones.

Empaquetamiento de las chapas.- Las chapas apiladas al final de la mesa de salida, son transferidas manualmente una a una a un soporte de empaquetamiento llamado "pallet". Los pallet utilizados para formar y contener los paquetes de chapas son de madera tienen una resistencia de carga aproximada de 2.500 Kg., por lo tanto la cantidad de chapas apiladas y empaquetas en cada uno está en función a su capacidad.

Este tipo de operación originaba el agotamiento físico del personal de esta máquina durante la jornada de trabajo causando malestar e incomodidad.

Una de las misiones de la compañía es mantener a su personal en un ambiente sano y productivo, por lo tanto la situación descrita anteriormente era todo lo contrario, convirtiéndose en otro problema más que se debía resolver.

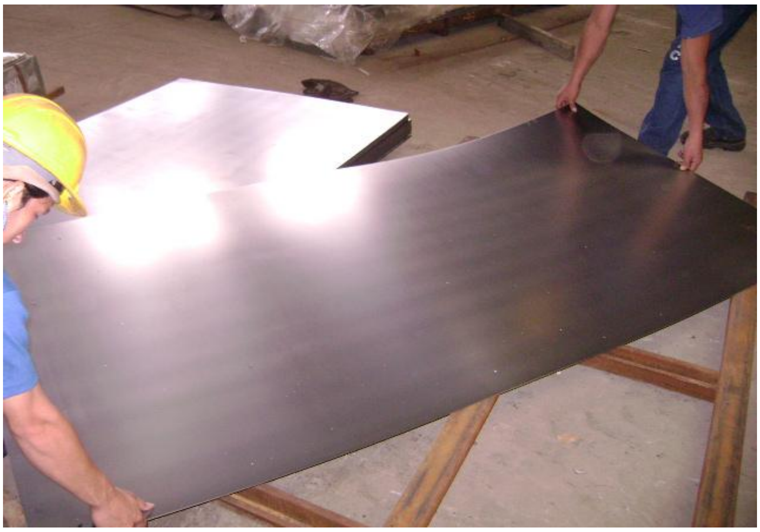

FIGURA 1.31 TRABAJADORES ARMANDO LOS PAQUETES DE CHAPAS

Evacuación de los paquetes de chapas.- La evacuación de los paquetes de chapas desde el lugar de apilamiento al final de la

mesa de salida hasta la zona de producto terminado, es realizada por medio de un equipo de carga denominado "montacargas" cuya capacidad es de 5.000 Kg. Hecha esta evacuación se coloca otro pallet para ser llenado con más chapas, repitiéndose este trabajo hasta empaquetar y evacuar hasta la última chapa apilada

FIGURA 1.32 MONTACARGAS EVACUANDO LOS PAQUETES DE CHAPA

CAPÍTULO 2

2. OPTIMIZACION DE LA LINEA DE PRODUCCION

Para optimizar la línea de producción se estudiaron y analizaron todas las operaciones directas e indirectas que se realizaban en el trabajo de convertir la bobina en chapas alisadas, así como el funcionamiento de cada elemento de la máquina alisadora durante el proceso de conversión.

Todo lo antes descrito fue con la finalidad de obtener un mejor enfoque de lo que sucedía físicamente y el tiempo empleado en cada operación del proceso para luego realizar los correctivos pertinentes.

Con los resultados obtenidos del estudio y de las observaciones se pudo determinar los motivos por los cuales la calidad de las chapas alisadas no cumplían con las estándares adoptados y además los factores que incidían directa e indirectamente en la producción de las chapas, siendo esta producción el motivo principal para que el coeficiente de maquila sea mayor que el establecido.

Estudio de tiempos y métodos aplicados a la línea de producción

El estudio de tiempos y métodos fue la herramienta principal para visualizar de mejor manera todas las actividades que ocurrían durante el proceso de alisado así como los tiempos empleados para su ejecución en cada una de ellas que por lo general el resultado final es un valor promedio de los valores obtenidos en un periodo de tiempo.

El estudio de tiempos y métodos aplicado a la línea de producción en referencia se realizó en dos periodos diferentes, el primero antes de las mejoras realizadas durante los 21 días laborables del mes de noviembre del año 2007 y el segundo después de las mejoras, siendo este periodo los 19 días laborables de Febrero del 2008.

El primer periodo se lo realizó con el objeto de determinar las falencias antes descritas en la línea de proceso y el segundo para comprobar los resultados obtenidos por las mejoras implantadas.

TABLA 4

ESTUDIO DE TIEMPOS Y METODOS APLICADO AL PROCESO DE ALISADO

	Días de Noviembre 2007																					TIEMPO
Operaciones realizadas para alisar bobinas cuyos pesos fluctuan alrededor de 5.200 kg	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	PROM. MES
	MINUTOS																					
Recepción de la orden de trabajo	3	2	3	4	5	2	4	3	4	4	4	4	3	5	2	3	4	5	3	4	4	4
Solicitud de la bobina en la bodega de materia prima	10	11	12	11	11	11	11	10	10	12	13	13	15	9	10	9	9	10	11	10	10	11
Preparación de la bobina	15	20	15	12	13	13	14	15	14	14	13	14	15	14	15	14	15	15	15	15	14	14
Calibración del tren de rodillos superiores del planchado	5	5	5	5	5	5	3	3	4	3	3	3	4	4	5	3	4	3	3	3	3	4
Calibración de la abertura entre cuchillas del cortador	9	10	10	10	10	9	9	9	9	9	8	9	8	9	9	9	9	9	10	8	9	9
Enhebrada de la bobina	15	17	17	17	17	15	15	15	16	16	15	16	14	15	16	16	15	15	15	15	15	16
Planchado de las chapas	90	90	91	90	91	92	90	90	90	91	91	90	91	90	90	90	91	91	90	90	91	90
Reaustes por descuadres de las chapas	14	14	15	13	14	15	15	15	15	15	15	15	14	14	15	15	15	15	15	15	15	15
Armado y ensunchado del primer paquete de chapas	102	100	103	101	99	97	102	102	101	100	100	100	101	103	102	101	101	101	100	100	100	101
Evacuación del primer paquete de chapas	7	7	7	7	6	5	6	6	5	6	6	6	6	6	7	6	7	6	6	6	7	6
Armado y ensunchado del segundo paquete de chapas	98	98	100	99	99	100	100	100	102	101	101	102	102	101	102	102	102	102	102	101	100	101
Evacuación del segundo paquete de chapas	6	7	7	7	6	6	6	6	6	6	5	6	6	6	5	6	6	6	6	6	6	6
TOTAL MINUTOS	374	381	385	376	376	370	375	374	376	377	374	378	379	376	378	374	378	378	376	373	374	376

NOTA: El total de minutos registrado es el tiempo consumido para procesar una bobina

2.2 Determinación de las causas que afectan la calidad de las chapas alisadas

Del resultado obtenido por la aplicación del estudio de tiempos y métodos en el año 2007, además de la observación física del funcionamiento de los elementos que conforman la máquina alisadora, se determinó que las causas que afectan la calidad de las chapas alisadas, las mismas que originan la obtención del 12% de la producción obtenida mensualmente de chapas que no cumplen con el control de calidad establecido, son:

- La utilización del desenrrollador inapropiado
- La falta de un elemento en el cortador que sujete la chapa al momento del corte y
- La falta de un elemento en el planchador que guía a la chapa cuando esta entra al tren aplanador.

Desenrrollador inapropiado.- Observando directamente la operación que efectúa el desenrrollador durante el proceso de alisado y en los defectos producidos en las chapas obtenidas, se determinó que los conos de este no son los indicados para servir como elemento de soportes a las bobinas en proceso ya que estas son de material fino susceptible a dañarse. Por lo tanto una de las causas que afecta la calidad en las chapas obtenidas es el desenrrollador utilizado por la máquina alisadora.

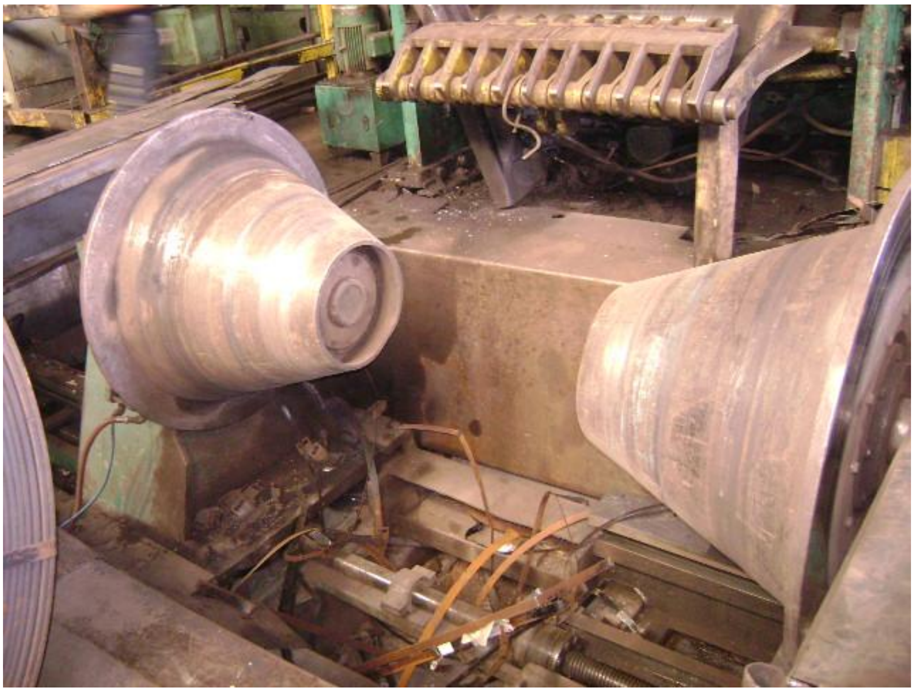

FIGURA 2.1 LOS CONOS DEL DESENRROLLADOR

Falta de un elemento fijador de chapa en el cortador.- Basados en la observación directa durante el funcionamiento del cortador y en los defectos producidos en las chapas cuando esta pasa por esta etapa, se determinó que el cortador de esta línea necesita un elemento que afirme la chapa al momento del corte puesto que esta se desplaza cuando es cortada, ocasionando los consecuentes descuadres, otras máquina similar tienen incorporado un elemento denominado “Prensachapas”, cuya función es fijar la chapa al momento del corte, por lo tanto otra de las causa que afecta la calidad de las chapas obtenidas es la falta de un prensachapas.

FIGURA 2.2 PRENSACHAPAS DE LA CORTADORA DE FLEJES

Guías para las chapas a la entrada del planchador.- Utilizando la observación directa en el desempeño del planchador y en los defectos obtenidos en las chapas al momento del planchado, se determinó que este elemento necesitaba un dispositivo que guíe la chapa a la entrada del tren aplanador para que no se desalinee de su posición correcta provocando los consecuentes descuadres mencionados y además la paralización del proceso para realizar las correcciones respectivas, por lo tanto otra causa que afecta la calidad de las chapas producidas es la falta de guías para la chapa a la entrada en el planchador.

FIGURA 2.3 GUÍAS DE ENTRADA DE LA CORTADORA DE ROLLOS

2.3 Determinación de los factores que elevan el valor del coeficiente de maquila.

El componente principal que afecta el valor del coeficiente de maquila es la producción, por lo tanto utilizando el estudio de métodos y tiempos como herramienta principal y la observación física, determinamos que el factor principal que afecta la producción elevando el valor del coeficiente de maquila es el tiempo en que no se produce, a este se lo llama “tiempo muerto”, se generan tiempos muertos cuando se debe alinear la chapa debido a su desalineamiento durante el proceso, también al ocurrido para formar los paquetes de chapas, y además al que se puede disminuir cuando se procede a ejecutar la fase de solicitud y preparación de la bobina por parte del operador de la máquina.

Tiempos muertos por reajuste de la chapa debido al desalineamiento.- Por medio del estudio de métodos y tiempos aplicado a la línea de proceso se determinó que el tiempo utilizado en corregir las desalineaciones de la chapa durante el proceso provocando la paralización de este, es uno de los factores que elevan el valor del coeficiente da maquila.

Tiempos muertos por la conformación de los paquetes de chapas.- Con los resultados del estudio de tiempos y métodos en cuanto al tiempo utilizado para armar los paquetes de chapas se determina que las chapas apiladas al final de la mesa de salida impiden el proceso de otra bobina ya que el área de apilamiento se encuentra ocupada y el tiempo empleado para conformar los paquetes y continuar con el proceso es otro factor que eleva el valor del coeficiente de maquila.

Tiempos muertos por solicitud y preparación de bobina.- Revisando los datos obtenidos en el estudio de tiempos y métodos sobre los tiempos empleados para solicitar y preparar la bobina por parte del operador es notorio que este tipo de operación podría realizarla otra persona y así de esta manera se trabajaría paralelamente las etapas de calibraciones acortando en algunos minutos todo el proceso, consideramos que este tiempo mal empleado es otro factor que eleva el valor del coeficiente de maquila.

2.4 Planteamiento de los correctivos y mejoras a aplicarse

Determinadas las causas que afectan la calidad de las chapas alisadas, y los factores que influyen para que la producción de las mismas no aumente, se plantearon los siguientes correctivos:

Cambio del desenrrollador utilizado.- Puesto que una de las causas de obtención del porcentaje de defectos era el daño de las última chapas de la bobinas en proceso debido a los conos del desenrrollador utilizado, se planteó la instalación de otro que no produjera el daño que se quería eliminar.

Instalación de un elemento de fijación en el cortador.- Para evitar que las chapas al momento del corte en el cortado se muevan provocando el consecuente descuadre como parte de la reducción del porcentaje de chapas obtenidas con defecto, se planteó la construcción e instalación de un elemento de fijación que las inmovilice evitando el defecto antes mencionado.

Instalación de un elemento que guíe la chapa a la entrada del planchador.- Para eliminar las paralizaciones repetitivas del proceso por los constantes desalineamiento de la chapa y evitar los consecuentes descuadres como parte de la reducción del porcentaje de chapas obtenidas con defectos, se planteó la construcción e instalación de un elemento que guíe a esta a la entrada del planchado.

Reducir tiempos en actividades previo al enhebrado de la bobina.- Para evitar la pérdida de tiempo debido a que el operador tenía que realizar las actividades de solicitud de la bobina en la bodega de materia prima, de preparación de la bobina, de la calibración el tren planchador y la calibración de las cuchillas del cortador antes de enhebrar la bobina, se planteó la necesidad de delegar a otra persona la realización de alguna actividad de estas, para que al mismo tiempo se pudiera trabajar paralelamente en las actividades antes descritas.

Específicamente se designó al ayudante de la máquina para que realizara las actividades de solicitud y preparación de la bobina.

Reducir el tiempo empleado para apilar, empaquetar y evacuar los paquetes de chapas.- Debido a que, el excesivo tiempo empleado en apilar, empaquetar y evacuar los paquetes de chapas era uno de los factores de que la producción no aumente, y a la vez estas operaciones causaban el agotamiento físico de los trabajadores que laboran en esta línea, se planteó modificar la manera de realizar las operaciones antes mencionadas por otras más rápidas y efectivas que acorten el tiempo de proceso y de esta manera utilizar este tiempo para procesar más bobinas y a la vez con menos esfuerzo por parte del personal.

2.5 Selección de los equipos que se instalarán para cumplir con los objetivos propuestos

Desenrrollador del tipo mandril expansible.- El primer equipo seleccionado para optimizar la línea de proceso fue un desenrrollador del tipo mandril expansible, el cual reemplazó al que era utilizado hasta ese momento. Este desenrrollador era utilizado en la línea de alisado de chapas de acero laminados en caliente, y lo que se hizo fue intercambiar desenrrolladores para ambas líneas.

El principio de funcionamiento es hidráulico, es decir que las uñas del mandril se expanden o se contraen debido al desplazamiento interno de eslabones accionados por un eje unido a un pistón hidráulico, sin deteriorar la parte interior de la bobina y causar los defectos en las últimas chapas alisadas.

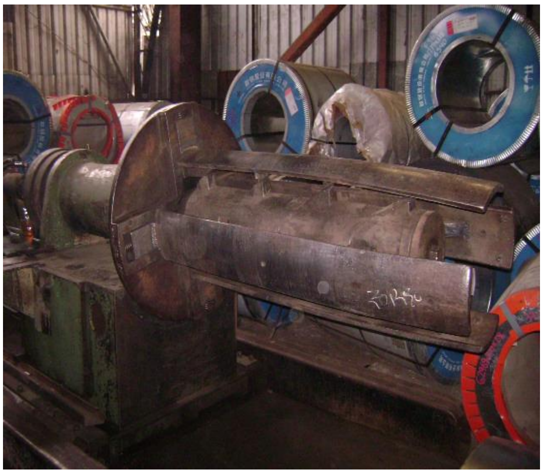

FIGURA 2.4 DESENRROLLADOR DEL TIPO MANDRIL EXPANDIBLE

Prensachapas del cortador.- Este prensachapas fue construido en un taller mecánico según los requerimientos especificados teniendo presente las características físicas y de operación del cortador, su forma básica es, cuatro dispositivos de sujeción montados sobre un bastidor el cual se adosó a la parte móvil del cortador.

Cada dispositivo de sujeción esta conformado por un disco pisador, un eje columna, un resorte y una guía de deslizamiento.

El principio de funcionamiento correspondiente es el de ejercer presión sobre la chapa por parte de los discos pisadores utilizando la energía potencial elástica de los resortes, esto ocurre cuando se inicia el corte de la chapa, donde la parte móvil en sentido vertical del cortador denominado "cortina" baja la cuchilla apernada a ella, efectuando un corte similar al de una guillotina, pero antes que la cuchilla toque la chapa, los discos pisadores del prensachapas que también son desplazados en el mismo sentido, sujetan la chapa para que de esta manera no se mueva de su posición y no se produzca el consecuente descuadre, después del corte la cortina vuelve a su posición superior liberando la chapa de la presión de los discos pisadores.

El tiempo de instalación y prueba de este prensachapas fue de un día.

FIGURA 2.5 PRENSACHAPAS

Guías de entrada al planchador.- Las guías de entrada utilizadas fueron fabricadas en un taller mecánico de acuerdo a las características, requerimientos y disposición física en el planchador.

Están conformadas por un bastidor acanalado transversalmente donde se alojan dos dados deslizantes uno en cada extremo del bastidor, los dados son regulado en su desplazamiento por ejes roscados con su respectivas manivelas, montado en cada dado se sitúa una guía que tiene la forma de una barra acanalada cuyas medidas son 80 mm de ancho por 500 mm de largo y 30 mm de espesor y el canal de 30 mm de profundidad, 10 mm de ancho y a todo lo largo de la barra; dos polines locos a la entrada de las guías y una bancada que soporta a todo los demás elementos.

El principio de funcionamiento se base en la regulación de la abertura existente entre las guías acanaladas por medio de los ejes roscados para de esta manera guiar la chapa que pasa por el planchador y se mantenga alineada en esa posición hasta que termine todo el proceso evitando así el descuadre de la misma.

El tiempo de instalación, calibración y prueba fue de dos días.

FIGURA 2.6 GUÍAS DE ENTRADA AL PLANCHADOR

Carro para apilar las chapas y evacuar los paquetes de estas.- Se fabricaron 2 carros con las medidas y capacidades adecuadas para soportar un paquete de chapas de aproximadamente 2.500 Kg. de peso utilizándose perfiles estructurales para la fabricación de los marcos o plataformas de los carros y se instalaron en cada uno con cuatro ruedas tipo garruchas adecuadamente seleccionadas, tanto los marcos como las garruchas fueron solicitadas de acuerdo a los requerimientos especificados y construidas en un taller mecánico local.

Debido a la utilización de estos carros fue modificada la manera de proceder en cuanto al apilamiento, empaquetamiento y evacuación de los paquetes de chapas.

FIGURA 2.7 CARRO APILADOR Y EVACUADOR

CAPÍTULO 3

3. EVALUACION DE LOS RESULTADOS

Como consecuencia de las aplicaciones de los correctivos y las mejoras descritas en el capitulo 2 se han obtenido los resultados perseguidos en cuanto a la manera de proceder en la ejecución de las diferentes etapas en el proceso de alisado y el tiempo empleado para realizarlas, así como los valores obtenidos para el porcentaje de chapas con defectos que provocan que estas no cumplan con el control de calidad establecido y además para la producción de chapas alisadas y su consecuente coeficiente de maquila.

Del estudio de tiempos y métodos realizado en Febrero del 2008 se obtiene como resultado que el tiempo empleado para procesar una bobina es 167 minutos, que al compararlo con los datos del estudio realizado en Noviembre del 2007 se determina que este tiempo se ha reducido en un 55.58 %, siguiendo el presente diagrama de flujo.

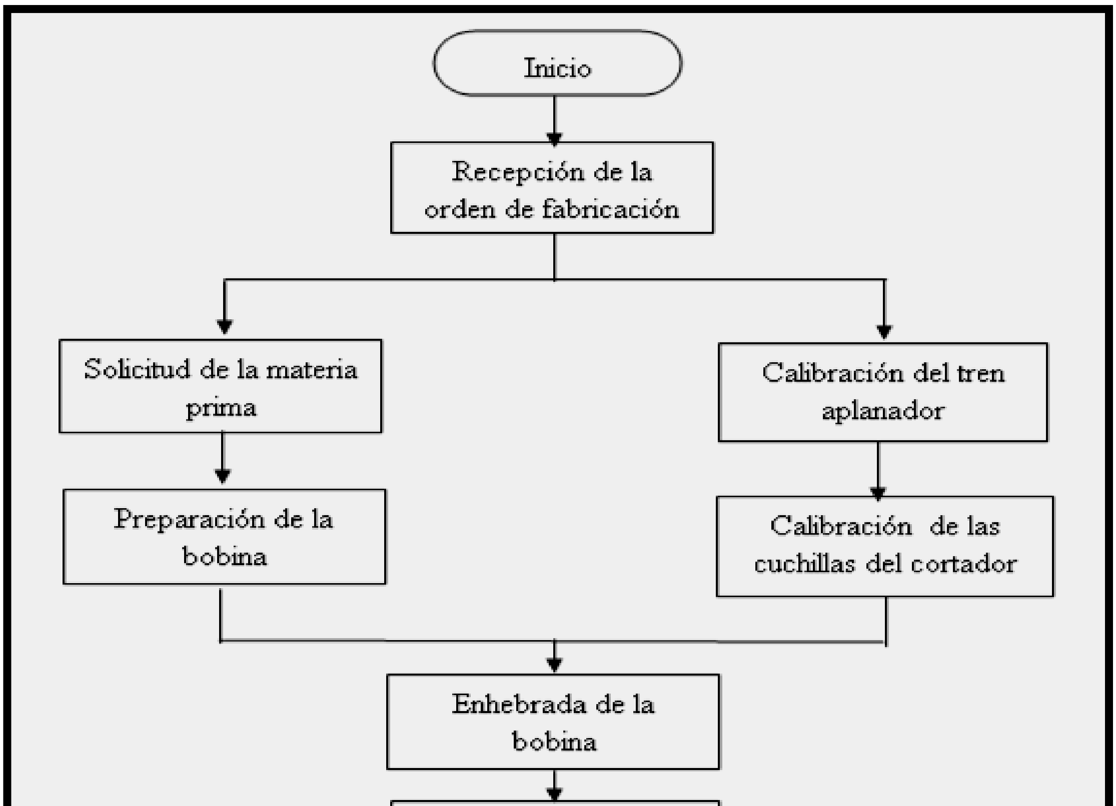

FIGURA 3.1 DIAGRAMA DE FLUJO DEL PROCESO DE ALISADO DESPUÉS DE LAS MEJORAS REALIZADAS

TABLA 5

ESTUDIO DE TIEMPOS Y METODOS APLICADO AL PROCESO DE ALISADO

Operaciones realizadas para alisar bobinas cuyos pesos fluctuan alrededor de 5.200 kg	Dias de Febrero 2008																			TIEMPO PROM. MES
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
	MINUTOS																			
Recepción de la orden de trabajo	3	5	3	4	3	3	4	3	4	4	3	4	3	4	4	4	3	4	4	4
Calibración del tren de rodillos superiores del planchado	5	5	5	5	5	5	3	3	4	3	4	3	4	4	5	3	4	3	3	4
Calibración de la abertura entre cuchillas del cortador	9	10	10	10	10	9	9	9	9	9	8	9	8	9	9	9	9	9	10	9
Solicitud y preparación de la bobina	16	11	12	15	11	15	14	15	10	12	12	13	15	15	14	15	15	14	15	14
Enhebrada de la bobina	15	17	17	17	17	15	15	15	16	16	16	16	14	15	16	16	15	15	15	16
Planchado de las chapas (parte primera)	46	45	42	44	43	45	44	45	44	44	45	46	46	45	44	44	45	44	45	45
Ensunchado del primer paquete de chapas	12	11	10	10	10	10	10	11	12	11	11	11	11	11	10	9	10	10	10	11
Mover carro con primer paquete a la zona de evacuación	6	5	5	5	6	6	5	6	5	6	5	6	5	6	5	6	5	5	6	5
Planchado de las chapas (parte segunda)	44	44	44	45	45	45	44	44	45	46	44	45	45	45	45	44	44	44	44	45
Ensunchado del segundo paquete de chapas	10	10	10	10	11	11	11	11	12	12	12	12	11	10	10	10	10	10	10	11
Mover carro con segundo paquete a la zona de evacuación	5	6	4	6	5	5	4	6	4	5	4	5	4	4	4	5	4	4	5	5
TOTAL MINUTOS	171	169	162	171	166	169	163	168	165	168	164	170	166	168	166	165	164	162	167	167

NOTA: El total de minutos registrado es el tiempo consumido para procesar una bobina

3.1 Determinación del porcentaje de chapas que no cumplen con la calidad normalizada

Los datos registrados mensualmente durante el primer semestre del año en curso al respecto de los defectos encontrados en las chapas producidas mostrados como porcentaje, nos indican que el valor total fue alrededor del 1.2 %, siendo estos los indicados en la siguiente tabla:

TABLA 6

PORCENTAJES DE DEFECTOS GENERADOS EN LAS CHAPAS DURANTE EL PROCESO PRODUCTIVO

	Año 2008						Promedio semestre
TIPOS DE DEFECTOS	ene	feb	mar	abr	may	jun	
	PORCENTAJE						
Chapas descuadradas	1.0	0.1	0.1	0.1	0.1	0.1	**0.3**
Chapas con ondulaciones	0.5	0.5	0.6	0.6	0.6	0.6	**0.6**
Chapas con bordes con rebaba	0.0	0.4	0.4	0.4	0.4	0.5	**0.4**
Chapas con bordes rotos	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
PORCENTAJES TOTALES	**1.5**	**1.0**	**1.1**	**1.1**	**1.1**	**1.2**	**1.2**

Comparando los resultado obtenidos en el primer semestre del año 2008 con los del año

2007 tenemos que el porcentaje de chapas con defectos consideradas como de segunda calidad disminuyó en un 90 %.

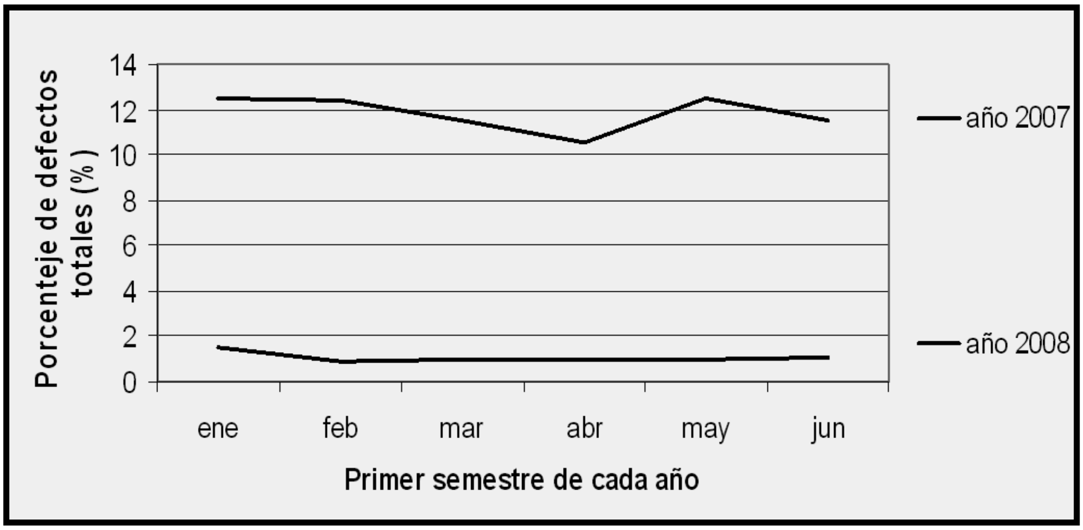

FIGURA 3.2 COMPARACION ENTRE PORCENTAJES DE DEFECTOS OBTENIDOS EN LAS CHAPAS DURANTE EL PROCESO PRODUCTIVO

3.2 Determinación del nuevo valor de coeficiente de maquila

En la siguiente tabla se indican los valores de Producciones de chapas obtenidas y sus consecuentes coeficientes de maquila.

TABLA 7

VALORES DE PRODUCCIONES, COSTOS GENERADOS Y COEFICIENTES DE MAQUILA OBTENIDOS DURANTE EL PRIMER SEMESTRE DEL AÑO 2008

	ene	feb	mar	abr	may	jun	Promedio semestre
Producciones (TM)	242	241	240	240	240	245	241
Costos ($)	4,800	4,800	4,850	4,850	4,850	4,850	4,833
Coeficiente de maquila ($ / TM)	19.83	19.92	20.21	20.21	20.21	19.80	20.03

Los datos registrados mensualmente durante el primer semestre del año en curso nos indican que la producción de chapas alisadas aumentó a 240 toneladas métricas aproximadamente que comparadas con las del año 2007 tubo un incremento del 100 %

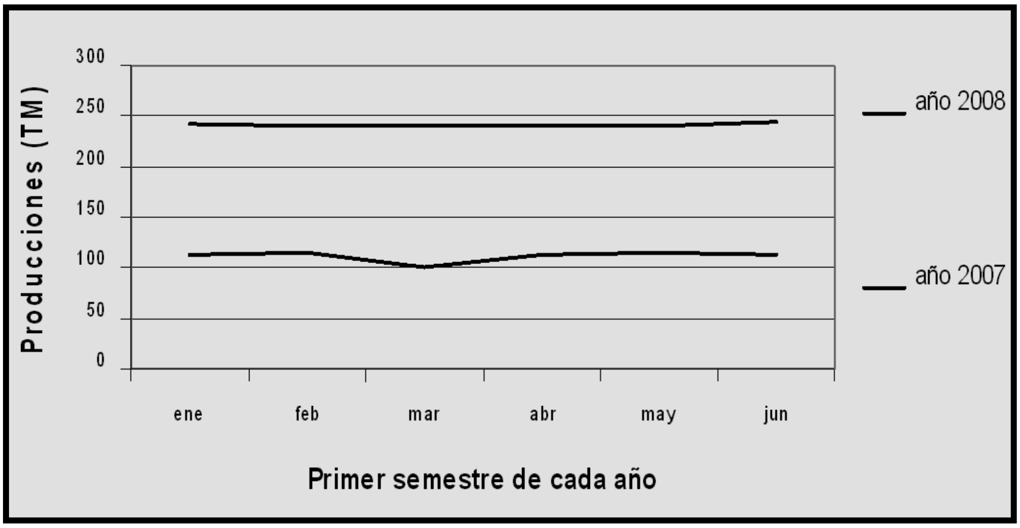

FIGURA 3.3 COMPARACION ENTRE PRODUCCIONES OBTENIDAS

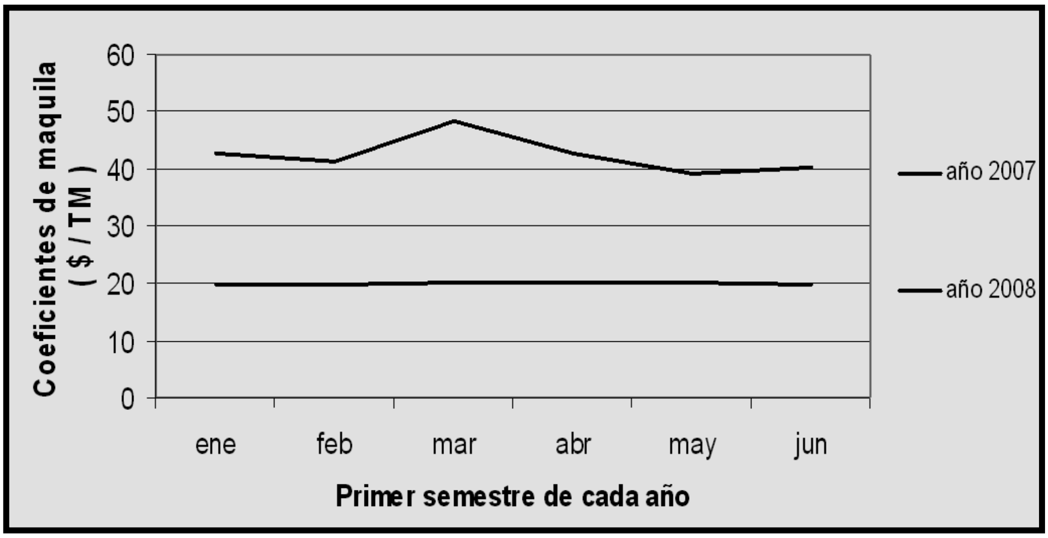

FIGURA 3.4 COMPARACION ENTRE PRODUCCIONES OBTENIDOS

Como consecuencia en el incremento de la producción de chapas, el valor para el coeficiente de maquila durante el primer semestre del año 2008 disminuyó a 20 dólares la tonelada métrica que comparado con el obtenido en el primer semestre del año 2007 este valor disminuyo en un 52.17 %

3.3 Determinación del tiempo de reposición del capital invertido en las mejoras aplicadas

El valor invertido en optimizar esta línea de proceso fue de acuerdo a la fabricación e instalación de los elementos seleccionados, como lo fueron el prensachapas, las guías de entrada, los carros evacuadotes, el cambio del desenrrolador y además de los dos estudios de tiempos y métodos realizados.

Este valor fue de $ 15.000, el mismo que está detallado de acuerdo a los rubros pagados mostrados en la tabla a continuación:

TABLA 8

COSTO DE INVERSION PARA OPTIMIZAR LA LINEA DE PROCESO

RUBRO	VALOR $
Estudios de tiempos y métodos	8.000
Construcción de las guías de entradas para el planchador	3.700
Construcción del prensachapas para el cortador	1.200
Cambio del desenrrollador	1.300
Construcción de dos carros evacuadores	800
TOTAL INVERTIDO	15.000

El tiempo de reposición del capital invertido se calculó empleando las siguientes consideraciones.

La producción de chapas alisadas aumentó de 120 a 240 TM manteniendo los costos iguales, entones cada mes que se produzca 240 TM se está ahorrando $4.800 que correspondería a la producción obtenida de 120 TM.

Por lo tanto los $ 15.000 invertidos para los $ 4.800 mensuales ahorrados da como resultado 3.13 meses, que sería el tiempo en el cual se repuso el capital invertido en la optimización de la línea estudiada.

CAPÍTULO 4

4. CONCLUSIONES Y RECOMENDACIONES

A continuación se presentan las conclusiones y recomendaciones producto de las acciones tomadas para optimizar la línea de proceso de alisado:

4.1 Conclusiones

- Antes de las mejoras realizadas el valor promedio mensual del coeficiente de maquila de la línea era $ 42 / TM después de las mejoras es $ 20 / TM, es decir el coeficiente de maquila disminuyó en un 52.17 %

- La producción promedio mensual de chapas alisadas era 120 TM después de las mejoras es 240 TM. es decir aumentó la producción de chapas en un 100%
- El promedio mensual del porcentaje de chapas producidas que no cumplían con el control de calidad establecido era el 12% y después de las mejoras es el 1.2 %, es decir disminuyó el porcentaje de chapas con defecto en un 90 %.

- Los cambios realizados en las operaciones de empaquetado de chapas, por medio de operaciones mecanizadas y condiciones de trabajo apropiadas y entrenamiento, el personal mejoró su desempeño.

- También se consiguieron otras mejoras y son las siguientes:

- Mejoramiento de la competitividad y algo muy importante, confiabilidad de los clientes en la calidad de nuestros productos

4.2 Recomendaciones

Durante el lapso de estudio para mejorar esta línea y sus respectivos cambios en los procedimientos así como en la instalación de nuevos maquinas complementarias, surgieron nuevas ideas para seguir optimizando la línea y de esta manera obtener mejores resultados en cuanto a aumentar y mejorar: producción, calidad, y costos,.

Se recomienda automatizar la línea que de acuerdo a datos estimados referentes a la eliminación de tiempos muertos se podría obtener un 25% más de producción, como consecuencia el coeficiente de maquila bajaría a $ 16 / TM y de esta manera se obtendría mayores márgenes de ganancias en la comercialización de estas chapas.

Además, posteriormente a la automatización se pensará en la adquisición o fabricación de un empaquetador, por medio de esta acción se podrá reducir el coeficiente de maquila hasta $ 14.66 / TM y se podría pensar en exportar este producto a otros países con menor ventajas competitivas

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APENDICE A: Norma ASTM A1008 / A1008M

APENDICE B: Norma ASTM A568 / A568M

Designation: A 1008/A 1008M – 04a

Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability[1]

This standard is issued under the fixed designation A 1008/A 1008M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers cold-rolled, carbon, structural, high-strength low-alloy, and high-strength low-alloy with improved formability steel sheet, in coils and cut lengths.

1.2 Cold rolled steel sheet is available in the designations as listed in 4.1.

1.3 *This specification does not apply to steel strip as described in Specification A 109.*

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.19 on Steel Sheet and Strip.

Current edition approved ~~Feb.~~ April 1, 2004. Published ~~February~~ April 2004. Originally approved in 2000. Last previous edition approved in 20034 as A 1008/A 1008M – 034.

*A Summary of Changes section appears at the end of this standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 109/A 109M Specification for Steel, Strip, Carbon (0.25 Maximum Percent), Cold Rolled
A 366/A 366M Specification for Commercial Steel (CS), Sheet, Carbon (0.15 Maximum Percentage), Cold-Rolled[3]
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 568/A 568M Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for
A 620/A 620M Specification for Drawing Steel (DS), Sheet, Carbon, Cold-Rolled[3]
A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
E 517 Test Method for Plastic Strain Ratio r for Sheet Metal
E 646 Test Method for Tensile Strain-Hardening Exponents (n-Values) of Metallic Sheet Materials

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of other terms used in this specification, refer to Terminology A 941.

3.1.2 *stabilization*—the addition of one or more nitride- or carbide-forming elements, or both, such as titanium and columbium, to control the level of the interstitial elements of carbon and nitrogen in the steel.

3.1.2.1 *Discussion*—Stabilizing improves formability and increases resistance to aging.

3.1.3 *vacuum degassing*—a process of refining liquid steel in which the liquid is exposed to a vacuum as part of a special technique for removing impurities or for decarburizing the steel.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aging*—loss of ductility with an increase in hardness, yield strength, and tensile strength that occurs when steel that has been slightly cold worked (such as by temper rolling) is stored for some time.

3.2.1.1 *Discussion*—Aging increases the tendency of a steel to exhibit stretcher strains and fluting.

4. Classification

4.1 Cold-rolled steel sheet is available in the following designations:

4.1.1 Commercial Steel (CS Types A, B, and C),

4.1.2 Drawing Steel (DS Types A and B),

NOTE 1—CS Type B and DS Type B describe the most common product previously included, respectively, in Specifications A 366/A 366M and A 620/A 620M.

4.1.3 Deep Drawing Steel (DDS),

4.1.4 Extra Deep Drawing Steel (EDDS),

4.1.5 Structural Steel (SS grades 25[170], 30[205], 33[230] Types 1 and 2, 40[275] Types 1 and 2, 50[340], 60[410], 70[480], and 80[550]).

4.1.6 High-Strength Low-Alloy Steel (HSLAS, in classes 1 and 2, in grades 45[310], 50[340], 55[380], 60[410], 65[450], and 70[480] in Classes 1 and 2), and

4.1.7 High-Strength Low-Alloy Steel with Improved Formability (HSLAS-F grades 50[340], 60[410], 70[480], and 80[550]).

4.1.7.1 *HSLAS-F steel has improved formability when compared to HSLAS. The steel is fully deoxidized, made to fine grain* practice and includes microalloying elements such as columbium, vanadium, zirconium, etc. The steel shall be treated to achieve inclusion control.

4.2 When required for HSLAS and HSLAS-F steels, limitations on the use of one or more of the microalloy elements shall be specified on the order.

4.3 *Cold-rolled steel sheet is supplied for either exposed or unexposed applications. Within the latter category, cold-rolled sheet* is specified either "temper rolled" or "annealed last." For details on processing, attributes and limitations, and inspection standards, refer to Specification A 568/A 568M.

5. Ordering Information

5.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to describe the required material. Examples of such information include, but are not limited to, the following:

5.1.1 ASTM specification number and year of issue,

5.1.2 Name of material and designation (cold-rolled steel sheet) (include grade, type, and class, as appropriate, for CS, DS, DDS, EDDS, SS, HSLAS, or HSLAS-F) (see 4.1);

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.
[3] Withdrawn.

5.1.2.1 When a type is not specified for CS or DS, Type B will be furnished (see 4.1);

5.1.2.2 When a class is not specified for HSLAS, Class 1 will be furnished (see 4.1);

5.1.2.3 When a type is not specified for SS33[230] and SS40[275], Type 1 will be furnished (see 4.1);

5.1.3 Classification (either exposed, unexposed, temper rolled, or annealed last) (see 4.3);

5.1.4 Finish (see 9.1);

5.1.5 Oiled or not oiled, as required (see 9.2);

5.1.6 Dimensions (thickness, thickness tolerance table (see 5.1.6.1), width, and whether cut lengths or coils);

5.1.6.1 As agreed upon between the purchaser and the producer, material ordered to this specification will be supplied to meet the applicable thickness tolerance table shown in Specification A 568/A 568M;

NOTE 2—Not all producers are capable of meeting all the limitations of the thickness tolerance tables in Specification A 568/A 568M. The purchaser should contact the producer regarding possible limitations prior to placing an order.

5.1.7 Coil size (must include inside diameter, outside diameter, and maximum weight);

5.1.8 Copper bearing steel (if required);

5.1.9 Quantity;

5.1.10 Application (part identification and description);

5.1.11 Special requirements (if required), and

5.1.12 A report of heat analysis will be supplied, if requested, for CS, DS, DDS, and EDDS. For materials with required mechanical properties, SS, HSLAS, and HSLAS-F, a report is required of heat analysis and mechanical properties as determined by the tension test.

NOTE 3—A typical ordering description is as follows: ASTM A 1008-XX, cold rolled steel sheet, CS Type A, exposed, matte finish, oiled, 0.035 by 30 in. by coil, ID 24 in., OD 48 in., max weight 15 000 lbs, thickness tolerance Table 18 of Specification A 568/A 568M, 100 000 lb, for part No. 4560, Door Panel.

or:

ASTM A 1008M-XX, cold-rolled steel sheet, SS grade 275, unexposed, matte finish, oiled, 0.88 mm by 760 mm by 2440 mm, thickness tolerance Table A1.15 of Specification A 568/A 568M, 10 000 kg, for shelf bracket.

6. General Requirements for Delivery

6.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 568/A 568M unless otherwise provided herein.

7. Chemical Composition

7.1 The heat analysis of the steel shall conform to the chemical composition requirements of the appropriate designation shown in Table 1 for CS, DS, DDS, and EDDS and in Table 2 for SS, HSLAS, and HSLAS-F.

7.2 Each of the elements listed in Table 1 and Table 2 shall be included in the report of the heat analysis. When the amount of copper, nickel, chromium, or molybdenum is less than 0.02 %, report the analysis as <0.02 % or the actual determined value. When

TABLE 1 Chemical Composition[A]
For Cold Rolled Steel Sheet Designations CS, DS, DDS, and EDDS

Designation	Composition, % Heat Analysis (Element Maximum Unless Otherwise Shown)													
	C	Mn	P	S	Al	Si	Cu[B]	Ni[B]	Cr[B,C]	Mo[B]	V	Cb	Ti	N
CS Type A[D,E,F,G]	0.10	0.60	0.030	0.035	...	...	0.20[H]	0.20	0.15	0.06	0.008	0.008	0.008[I]	...
CS Type B[D]	0.02 to 0.15	0.60	0.030	0.035	...	...	0.20[H]	0.20	0.15	0.06	0.008	0.008	0.008[I]	...
CS Type C[D,E,F,G]	0.08	0.60	0.10	0.035	...	...	0.20[H]	0.20	0.15	0.06	0.008	0.008	0.008[I]	...
DS Type A[E,J]	0.08	0.50	0.020	0.030	0.01 min	...	0.20	0.20	0.15	0.06	0.008	0.008	0.008[I]	...
DS Type B	0.02 to 0.08	0.50	0.020	0.030	0.02 min	...	0.20	0.20	0.15	0.06	0.008	0.008	0.008[I]	...
DDS[F,G]	0.06	0.50	0.020	0.025	0.01 min	...	0.20	0.20	0.15	0.06	0.008	0.008	0.008[I]	...
EDDS[K]	0.02	0.40	0.020	0.020	0.01 min	...	0.10	0.10	0.15	0.03	0.008	0.10	0.15	...

[A] Where an ellipsis (. . .) appears in the table, there is no requirement, but the analysis result shall be reported.

[B] The sum of copper, nickel, chromium, and molybdenum shall not exceed 0.50 % on heat analysis. When one or more of these elements is specified by the purchaser, the sum does not apply, in which case only the individual limits on the remaining elements shall apply.

[C] Chromium is permitted, at the producer's option, to 0.25 % maximum when the carbon content is less than or equal to 0.05 %. In such case the limit on the sum of the four elements in Footnote B does not apply.

[D] When an aluminum deoxidized steel is required for the application, it is permissible to order Commercial Steel (CS) to a minimum of 0.01 % total aluminum.

[E] Specify Type B to avoid carbon levels below 0.02 %.

[F] It is permissible to furnish as a vacuum degassed or chemically stabilized steel, or both, at the producer's option.

[G] For carbon levels less than or equal to 0.02 %, it is permissible to use columbium or titanium, or both, as stabilizing elements at the producer's option. In such cases, the applicable limit for columbium shall be 0.10 % max. and the limit on titanium shall be 0.15 % max.

[H] When copper steel is specified, the copper limit is a minimum requirement. When copper steel is not specified, the copper limit is a maximum requirement.

[I] Except for EDDS, titanium is permitted, at producer's option, to 0.025 % provided the ratio of % titanium to % nitrogen does not exceed 3.4.

[J] It is permissible to furnish DS Type A as a vacuum degassed steel, at the producers option.

[K] Shall be furnished as a vacuum degassed and stabilized steel.

TABLE 2 Chemical Composition[A]
For Cold Rolled Steel Sheet Designations SS, HSLAS, and HSLAS-F

Designation	C	Mn	P	S	Al	Si	Cu[B,C]	Ni[B]	Cr[B]	Mo[B]	V	Cb	N
	% Heat Analysis, Element Maximum unless otherwise shown												
SS													
Grade 25 [170]	0.20	0.60	0.035	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
Grade 30 [205]	0.20	0.60	0.035	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
Grade 33 [230] Type 1	0.20	0.60	0.035	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
Grade 33 [230] Type 2	0.15	0.60	0.20	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
Grade 40 [275] Type 1	0.20	0.90	0.035	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
Grade 40 [275] Type 2	0.15	0.60	0.20	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
Grade 50 [340]	0.20	0.70	0.035	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
Grade 60 [410]	0.20	0.70	0.035	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
Grade 70 [480]	0.20	0.70	0.035	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
Grade 80 [550]	0.20	0.60	0.035	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
HSLAS[D]													
Grade 45 [310] Class 1	0.22	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	. . .
Grade 45 [310] Class 2	0.15	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	. . .
Grade 50 [340] Class 1	0.23	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	. . .
Grade 50 [340] Class 2	0.15	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	. . .
Grade 55 [380] Class 1	0.25	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	. . .
Grade 55 [380] Class 2	0.15	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	. . .
Grade 60 [410] Class 1	0.26	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	. . .
Grade 60 [410] Class 2	0.15	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	E
Grade 65 [450] Class 1	0.26	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	E
Grade 65 [450] Class 2	0.15	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	E
Grade 70 [480] Class 1	0.26	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	E
Grade 70 [480] Class 2	0.15	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	E
HSLAS-F[D,F]													
Grade 50[340], 60[410], 70[480], and 80[550]	0.15	1.65	0.020	0.025	. . .	. . .	0.20	0.20	0.15	0.06	. . .	. . .	E

[A] Where an ellipsis (. . .) appears in the table, there is no requirement but, the analysis shall be reported.

[B] The sum of copper, nickel, chromium, and molybdenum shall not exceed 0.50 %. When one or more of these elements are specified by the purchaser, the sum does not apply, in which case, only the individual limits on the remaining unspecified elements will apply.

[C] When copper is specified, the copper limit is a minimum requirement. When copper steel is not specified, the copper limit is a maximum requirement.

[D] For HSLAS steels, it is permissible to add columbium and vanadium singly or in combination.

[E] The purchaser has the option of restricting the nitrogen content. It should be noted that, depending on the microalloying scheme (for example, use of Vanadium) of the producer, nitrogen may be a deliberate addition. Consideration should be made for the use of nitrogen binding elements (for example, Vanadium, Titanium).

[F] These steels shall also contain one or more of the following elements: Vanadium, Titanium, and Columbium. Other alloying elements are permissible, but are not required.

the amount of vanadium, columbium, or titanium is less than 0.008 %, report the analysis as <0.008 % or the actual determined value.

7.3 *Sheet steel grades defined by this specification are suitable for welding if appropriate welding conditions are selected.* For certain welding processes, if more restrictive composition limits are desirable, they shall be specified at the time of inquiry and confirmed at the time of ordering.

8. Mechanical Properties

8.1 *CS, DS, DDS, and EDDS:*

8.1.1 Typical nonmandatory mechanical properties for CS, DS, DDS and EDDS are shown in Table 3.

8.1.2 The material shall be capable of being bent, at room temperature, in any direction through 180° flat on itself without cracking on the outside of the bent portion (see Section 14 of Test Methods and Definitions A 370).

8.1.3 Sheet of these designations except for EDDS are subject to aging dependent upon processing factors such as the method of annealing (continuous annealing or box annealing), and chemical composition. For additional information on aging, see Appendix X1 of Specification A 568 A 568M.

8.1.4 EDDS steel is stabilized to be nonaging and so is not subject to stretcher strains and fluting. Other steels are processed to be nonaging; please consult your supplier.

8.2 *SS, HSLAS and HSLAS-F:*

8.2.1 The available strength grades for SS, HSLAS and HSLAS-F are shown in Table 4.

8.2.2 *Tension Tests:*

8.2.2.1 *Requirements*— Material as represented by the test specimen shall conform to the mechanical property requirements specified in Table 4. These requirements do not apply to the uncropped ends of unprocessed coils.

8.2.2.2 *Number of Tests*— Two tension tests shall be made from each heat or from each 50 tons [45 000 kg]. When the amount of finished material from a heat is less than 50 tons [45 000 kg], one test shall be made. When material rolled from heat differs 0.050 in. [1.27 mm] or more in thickness, one tension test shall be made from the thickest and thinnest material regardless of the weight represented.

TABLE 3 Typical Ranges of Mechanical Properties[A] (Nonmandatory)[B]
For Cold Rolled Steel Sheet Designations CS, DS, DDS and EDDS

Designation	Yield Strength[C] ksi	Yield Strength[C] [MPa]	Elongation in 2 in. [50 mm] %[C]	r_m Value[D]	n Value[E]
CS Types A, B, and C	20 to 40	[140 to 275]	≥ 30	F	F
DS Types A and B	22 to 35	[150 to 240]	≥ 36	1.3 to 1.7	0.17 to 0.22
DDS	17 to 29	[115 to 200]	≥ 38	1.4 to 1.8	0.20 to 0.25
EDDS	15 to 25	[105 to 170]	≥ 40	1.7 to 2.1	0.23 to 0.27

[A] These typical mechanical properties apply to the full range of steel sheet thicknesses. The yield strength tends to increase, the elongation decreases and some of the formability values tend to decrease as the sheet thickness decreases.

[B] The typical mechanical property values presented here are nonmandatory. They are provided to assist the purchaser in specifying a suitable steel for a given application. Values outside of these ranges are to be expected.

[C] Yield Strength and elongation are measured in the longitudinal direction in accordance with Test Methods A 370.

[D] Average plastic strain ratio (r_m value) as determined by Test Method E 517.

[E] The strain hardening exponent (n-value) as determined by Test Method E 646.

[F] No typical properties have been established.

TABLE 4 ~~Mechanical Property Requirements~~[A]
For Cold Rolled Steel Sheet Designations SS, HSLAS, and HSLAS-F

Designation	Yield Strength, min ksi	Yield Strength, min [MPa]	Tensile Strength, min ksi	Tensile Strength, min [MPa]	Elongation in 2 in. or 50 mm, min, %
SS:					
Grade 25 [170]	25	[170]	42	[290]	26
Grade 30 [205]	30	[205]	45	[310]	24
Grade 33 [230] Types 1 and 2	33	[230]	48	[330]	22
Grade 40 [275] Types 1 and 2	40	[275]	52	[360]	20
Grade 50 [340]	50	[340]	65	[410]	18
Grade 60 [410]	60	[410]	75	[480]	12
Grade 70 [480]	70	[480]	85	[540]	6
Grade 80 [550]	80[B]	[550]	82	[565]	C
HSLAS:					
~~Grade 45 [310] Class 1~~	~~45~~	~~[310]~~	~~60~~	~~[410]~~	22
Grade 45 [310] Class 2	45	[310]	55	[380]	22
Grade 50 [340] Class 1	50	[340]	65	[450]	20
Grade 50 [340] Class 2	*50*	*[340]*	*60*	*[410]*	*20*
Grade 55 [380] Class 1	55	[380]	70	[480]	18
Grade 55 [380] Class 2	55	[380]	65	[450]	18
~~Grade 60 [410] Class 1~~	~~60~~	~~[410]~~	~~75~~	~~[520]~~	~~16~~
Grade 60 [410] Class 2	60	[410]	70	[480]	16
Grade 65 [450] Class 1	65	[450]	80	[550]	15
Grade 65 [450] Class 2	*65*	*[450]*	*75*	*[520]*	*15*
Grade 70 [480] Class 1	70	[480]	85	[585]	14
Grade 70 [480] Class 2	70	[480]	80	[550]	14
HSLAS-F:					
Grade 50 [340]	50	[340]	60	[410]	22
Grade 60 [410]	60	[410]	70	[480]	18
Grade 70 [480]	70	[480]	80	[550]	16
Grade 80 [550]	80	[550]	90	[620]	14

[A] For coil products, testing by the producer is limited to the end of the coil. Mechanical properties throughout the coil shall comply with the minimum values specified.

[B] On this full-hard product, the yield strength approaches the tensile strength and since there is no halt in the gage or drop in the beam, the yield point shall be taken as the yield stress at 0.5 % extension under load.

[C] There is no requirement for elongation in 2 in. for SS Grade 80.

8.2.2.3 Tension test specimens shall be taken at a point immediately adjacent to the material to be qualified.

8.2.2.4 Tension test specimens shall be taken from the full thickness of the sheet.

8.2.2.5 Tension test specimens shall be taken from a location approximately halfway between the center of the sheet and the edge of the material as rolled.

8.2.2.6 *Tension test samples shall be taken with the lengthwise axis of the test specimen parallel to the rolling direction (longitudinal test).*

8.2.2.7 *Test Method*— Yield strength shall be determined by either the 0.2 % offset method or the 0.5 % extension under load method unless otherwise specified.

8.2.3 *Bending Properties:*

8.2.3.1 The suggested minimum inside radii for cold bending are listed in Appendix X1 and is discussed in more detail in Specification A 568/A 568M (Section 6). Where a tighter bend radius is required, where curved or offset bends are involved, or where stretching or drawing are also a consideration, the producer shall be consulted.

9. Finish and Appearance

9.1 *Surface Finish:*

9.1.1 Unless otherwise specified, the sheet shall have a matte finish. When required, specify the appropriate surface texture and condition. For additional information, see the "Finish and Condition" section of Specification A 568/A 568M.

For additional information see "Finish and Condition" section of Specification A 568/A 568M.

9.2 *Oiling:*

9.2.1 Unless otherwise specified, the sheet shall be oiled.

9.2.2 When required, specify the sheet to be furnished not oiled (dry).

10. Retests and Resamples

10.1 *Retests*—If the results on an original tension test specimen are within 2 ksi [14 MPa] of the required tensile strength, within 1 ksi [7 MPa] of the required yield point, or within two percentage points of the required elongation, a retest shall be permitted for which one test specimen selected at random shall be tested. If the results of this retest specimen satisfy the specified mechanical properties and all other requirements of the applicable specification are satisfied, the material shall be accepted. Retests are permitted in accordance with Specification A 568/A 568M.

10.2 *Resamples*—Resamples are permitted in accordance with Specification A 568/A 568M.

11. Certification

11.1 A report of heat analysis shall be supplied, if requested, for CS, DS, DDS, and EDDS steels. For material with required mechanical properties, SS, HSLAS, and HSLAS-F, a report is required of heat analysis and mechanical properties as determined by the tension test.

11.2 The report shall include the purchase order number, the ASTM designation number and year date, product designation, grade, type or class, as applicable, the heat number, and as required, heat analysis and mechanical properties as indicated by the tension test.

11.3 A signature is not required on the test report. However, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

11.4 A Material Test Report, Certificate of Inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

12. Product Marking

12.1 In addition to the requirements of Specification A 568/A 568M, each lift or coil shall be marked with the designation shown on the order (CS (Type A, B, or C), DS (Type A or B), DDS, EDDS, SS, HSLAS, or HSLAS-F). The designation shall be legibly stenciled on the top of each lift or shown on a tag attached to each coil or shipping unit.

13. Keywords

13.1 carbon steel sheet; cold-rolled steel sheet; steel sheet; commercial steel; drawing steel; deep drawing steel; extra deep drawing steel; high-strength low-alloy steel; high-strength low-alloy steel with improved formability; structural steel

APPENDIXES

(Nonmandatory Information)

X1. BENDING PROPERTIES

X2. RELATED ISO STANDARDS

TABLE X1.1 Suggested Minimum Inside Radius for Cold Bending

NOTE 1—(*t*) Equals a radius equivalent to the steel thickness.

NOTE 2—The suggested radius should be used as a minimum for 90° bends in actual shop practice.

NOTE 3—Material which does not perform satisfactorily, when fabricated in accordance with the requirements, may be subject to rejection pending negotiation with the steel supplier.

Designation	Grade	Minimum Inside Radius for Cold Bending	
Structural Steel	25 [170]	½ *t*	
	30 [205]	1 *t*	
	33 [230]	1½ *t*	
	40 [275]	2 *t*	
	50 [340]	2½ *t*	
	60 [410]	3 *t*	
	70 [480]	4 *t*	
	80 [550]	*not applicable*	
High-Strength Low-Alloy Steel		Class 1	Class 2
	45[310]	1½ *t*	1½ *t*
	50[340]	2 *t*	1½ *t*
	55[380]	2 *t*	2 *t*
	60[410]	2½ *t*	2 *t*
	65[450]	3 *t*	2½ *t*
	70[480]	3½ *t*	3 *t*
High-Strength Low-Alloy Steel with Improved Formability	50[340]	1 *t*	
	60[410]	1½ *t*	
	70[480]	2 *t*	
	80[550]	2 *t*	

The ISO standards listed below may be reviewed for comparison with this ASTM standard. The relationship between the standards may only be approximate; therefore, the respective standards should be consulted for actual requirements. Those who use these documents must determine which specifications address their needs.

ISO 3574 Cold-Reduced Carbon Steel Sheet of Commercial and Drawing Qualities

ISO 4997 Cold-Reduced Steel Sheet of Structural Quality

ISO 13887 Cold-Reduced Steel Sheet of Higher Strength with Improved Formability

X3. HARDNESS PROPERTIES

TABLE X3.1 Typical Hardness Values

NOTE 1—The hardness values shown are at the time of shipment.

NOTE 2—Test for hardness shall be conducted in accordance with the requirements of Test Methods E 18.

NOTE 3—The hardness values are Rockwell B scale as measured or converted from the appropriate Rockwell scales.

NOTE 4—The typical hardness values apply to the full range of steel sheet thickness. Hardness tends to increase as the steel sheet thickness decreases.

NOTE 5—Hardness testing is commonly used to assess the relative formability of various designations of uncoated steel sheet. This assessment done by many users is recognized to be only an approximation of the relative formability and therefore cannot be used as a specification requirement.

Designation	Hardness-Rockwell B Scale
CS Type A	70 or less
CS Type B	70 or less
CS Type C	70 or less
DS Type A	60 or less
DS Type B	60 or less
DDS	55 or less
EDDS	45 or less

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue, A 1008/A 1008M – 04, that may impact the use of this standard. (Approved April 1, 2004.)

(1) The word "carbon" was added to 1.1.

Committee A01 has identified the location of selected changes to this standard since the last issue, A 1008/A 1008M – 03, that may impact the use of this standard. (Approved Feb. 1, 2004.)

(1) Revised Sections 4.1.5 and 4.2.
(2) Revised Section 5.1.11.
(3) Deleted S1, Supplementary Requirements.
(4) Revised Table 2 and Table 4.
(5) Revised Appendix X1.
(6) Added Test Methods E 18 to Referenced Documents.
(7) Added Appendix X3.

Committee A01 has identified the location of selected changes to this standard since the last issue, A 1008/A 1008M – 02 $^{\epsilon 1}$, that may impact the use of this standard. (Approved April 10, 2003.)

(1) Revisions were made to Tables 1 and 2.
(2) Revisions were made to the following sections: 4.1.7.1, 7.2, 7.3, 8.1.3, 8.1.4, 8.2.3.1, 9.1.1, and 9.2.2.

APENDICE B: Norma ASTM A568 / A568M

Designation: A 568/A 568M – 03

Standard Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for[1]

This standard is issued under the fixed designation A 568/A 568M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This specification covers the general requirements for steel sheet in coils and cut lengths. It applies to the following specifications that describe carbon steel and high-strength, low-alloy steel (HSLA) furnished as hot-rolled sheet and cold-rolled sheet: Specifications A 414/A 414M, A 424, A 606, A 659/A 659M, A 794, A 1008/A 1008M, and A 1011/A 1011M.

1.2 This specification is not applicable to hot-rolled heavy-thickness carbon sheet coils (ASTM Specification A 635/A 635M).

1.3 In case of any conflict in requirements, the requirements of the individual material specification shall prevail over those of this general specification.

1.4 For the purposes of determining conformance with this and the appropriate product specification referenced in 1.1, values shall be rounded to the nearest unit in the right hand place of figures used in expressing the limiting values in accordance with the rounding method of Practice E 29.

1.5 Annex A1 lists permissible variations in dimensions and mass (see Note 1) in SI [metric] units. The values listed are not exact conversions of the values listed in the inch-pound tables, but instead are rounded or rationalized values. Conformance to Annex A1 is mandatory when the "M" specification is used.

NOTE 1—The term *weight* is used when inch-pound units are the standard. However, under SI the preferred term is *mass*.

1.6 The values stated in either inch-pound units or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.7 This specification and the applicable material specifications are expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 414/A 414M Specification for Steel, Sheet, Carbon, for Pressure Vessels[2]

A 424 Specification for Steel, Sheet, for Porcelain Enameling[2]

A 606 Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance[2]

A 635/A 635M Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Carbon, Commercial Steel, Drawing Steel, Structural, High-Strength Low-Alloy, and High-Strength Low-Alloy with Improved Formability, Hot-Rolled, General Requirements for[2]

A 659/A 659M Specification for Commercial Steel (CS), Sheet and Strip, Carbon (0.16 Maximum to 0.25 Maximum Percent), Hot-Rolled[2]

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment[3]

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[2]

A 794 Specification for Commercial Steel (CS), Sheet, Carbon (0.16 % Maximum to 0.25 % Maximum), Cold-Rolled[2]

A 1008/A 1008M Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability[2]

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.19 on Steel Sheet and Strip.

Current edition approved April 10, 2003. Published May 2003. Originally approved in 1966. Last previous edition approved in 2002 as A 568 – 02.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.05.

*A Summary of Changes section appears at the end of this standard.

A 1011/A 1011M Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability[2]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[4]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[5]

E 290 Test Method for Bend Testing of Material for Ductility[6]

2.2 *Military Standards:*[7]

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage

2.3 *Federal Standards:*[7]

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *Steel Types:*

3.1.2 *carbon steel*—the designation for steel when no minimum content is specified or required for aluminum, chromium, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any element added to obtain a desired alloying effect; when the specified minimum for copper does not exceed 0.40 %; or when the maximum content specified for any of the following elements does not exceed the percentages noted: manganese 1.65, silicon 0.60, or copper 0.60.

3.1.2.1 *Discussion*—In all carbon steels small quantities of certain residual elements unavoidably retained from raw materials are sometimes found which are not specified or required, such as copper, nickel, molybdenum, chromium, etc. These elements are considered as incidental and are not normally determined or reported.

3.1.3 *high-strength, low-alloy steel*—a specific group of steels in which higher strength, and in some cases additional resistance to atmospheric corrosion or improved formability, are obtained by moderate amounts of one or more alloying elements.

3.1.4 *Product Types:*

3.1.5 *hot-rolled sheet*—manufactured by hot rolling slabs in a continuous mill to the required thickness and can be supplied in coils or cut lengths as specified.

(a) Hot-rolled carbon and high-strength low-alloy (HSLA) steel sheet is commonly classified by size as follows:

Coils and Cut Lengths	
Width, in.	Thickness, in.
12 to 48, incl	0.031 to 0.230, excl
Over 48	0.031 to 0.180, excl

Coils and Cut Lengths	
Width, mm	Thickness, mm
Over 300 to 1200, incl	0.8 to 6.0, excl
Over 1200	0.8 to 4.5, excl

3.1.6 *cold-rolled sheet*—manufactured from hot-rolled descaled coils by cold reducing to the desired thickness, generally followed by annealing to recrystallize the grain structure. If the sheet is not annealed after cold reduction it is known as full hard with a hardness of 84 HRB minimum and can be used for certain applications where ductility and flatness are not required.

(a) Cold-rolled carbon sheet is commonly classified by size as follows:

Width, in.	Thickness, in.
Through 12^A	Through 0.082
Over 12^B through 23 15/16	Through 0.142
Over 23 15/16	Through 0.142
Width, mm	Thickness, mm
To 300, incl^A	Through 2.0
Over 300^B	Through 4.0

^A Cold-rolled sheet coils and cut lengths, slit from wider coils with cut edge (only) and in thicknesses through 0.082 in. [2.0 mm] carbon 0.25 % maximum by cast analysis.

^B When no special edge or finish (other than matte, commercial bright, or luster finish) or single strand rolling of widths, or both under 24 in. [600 mm] is not specified or required.

(b) Cold-rolled high-strength low-alloy sheet is commonly classified by size as follows:

Width, in.	Thickness, in.
Through 12^A	0.019 through 0.082
Over 12^B	0.020 and over
Width, mm	Thickness, mm
To 300, incl^A	0.5 to 2.0, incl
Over 300^B	0.5 and Over

^A Cold-rolled sheet coils and cut lengths, slit from wider coils with cut edge (only) and in thicknesses 0.019 in. [0.5 mm] through 0.82 in. [2.0 mm] carbon 0.25 % maximum by cast analysis.

^B When no special edge or finish (other than matte, commercial bright, or luster finish) or single strand rolling of widths, or both under 24 in. [600 mm] is not specified or required.

3.1.6.1 *Discussion*—Steel products are available in various thickness, width, and length combinations depending upon equipment and processing capabilities of various manufacturers and processors. Historic limitations of a product based upon dimensions (thickness, width, and length) do not take into account current production and processing capabilities. To qualify any product for a particular product specification requires all appropriate and necessary tests be performed and that the results meet the limits prescribed in that product specification. If the necessary tests required by a product specification cannot be conducted, the product cannot be qualified to that specification. This general requirements specification contains permitted variations for the commonly available sizes. Permitted variations for other sizes are subject to agreement between the customer and the manufacturer or processor, whichever is applicable.

3.1.7 *retests, n*—an additional test, or tests, made from the original material when the original test did not meet the

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] Discontinued; see *1996 Annual Book of ASTM Standards*, Vol 03.05.

[6] *Annual Book of ASTM Standards*, Vol 03.01.

[7] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

appropriate acceptance criteria required by a product specification and the failure was mechanical in natures as described in Section 11.

3.1.8 *resample, n*—an additional test, or tests, made when the test on the original sample did not meet the appropriate acceptance criteria required by the product specification but possible requiring that the material in question have an appropriate amount discarded prior to securing the new sample or samples.

4. Materials and Manufacture

4.1 Unless otherwise specified, hot-rolled material shall be furnished hot-rolled, not annealed, not pickled.

4.2 Coil breaks, stretcher strains, and fluting can occur during the user's processing of hot-rolled or hot-rolled pickled sheet. When any of these features are detrimental to the application, the manufacturer shall be notified at time of ordering in order to properly process the sheet.

4.3 Cold-rolled carbon steel sheet is available as discussed in 10.2, 10.3, and in Table 1.

4.4 Unless specified as a full-hard product, cold-rolled sheet is annealed after being cold reduced to thickness. The annealed, cold-rolled sheet can be used as annealed last (dead soft) for unexposed end-use applications. When cold-rolled sheet is used for unexposed applications and coil breaks are a hazard in uncoiling, it may be necessary to further process the material. In this case the manufacturer should be consulted. After annealing, cold-rolled sheet is generally given a light skin pass to impart shape or may be given a heavier skin pass or temper pass to prevent the phenomenon known as stretcher straining or fluting, when formed. Temper passing also provides a required surface texture.

4.5 *Temper Rolling*:

4.5.1 Unless otherwise specified, cold-rolled sheet for exposed applications shall be temper rolled and is usually specified and furnished in the strain free condition as shipped. See Appendix X1, Effect of Aging of Cold-Rolled Carbon Steel Sheet on Drawing and Forming.

4.5.2 Cold-rolled sheet for unexposed applications may be specified and furnished "annealed last" or "temper rolled." "Annealed last" is normally produced without temper rolling but may be lightly temper rolled during oiling or rewinding. Unexposed temper-rolled material may be specified strain-free or nonfluting. Where specific hardness range or limit or a specified surface texture is required, the application is considered as exposed.

NOTE 2—Skin-passed sheet is subject to an aging phenomenon (see Appendix X1). Unless special killed (nonaging) steel is specified, it is to the user's interest to fabricate the sheet as soon as possible, for optimum performance.

5. Chemical Composition

5.1 *Limits:*

5.1.1 The chemical composition shall be in accordance with the applicable product specification. However, if other compositions are required for carbon steel, they shall be prepared in accordance with Appendix X2.

5.1.2 Where the material is used for fabrication by welding, care must be exercised in selection of chemical composition or mechanical properties to assure compatibility with the welding process and its effect on altering the properties.

5.2 *Cast or Heat Analysis:*

5.2.1 An analysis of each cast or heat of steel shall be made by the manufacturer to determine the percentage of elements specified or restricted by the applicable specification.

5.2.2 When requested, cast or heat analysis for elements listed or required shall be reported to the purchaser or to his representative.

5.3 *Product, Check, or Verification Analysis:*

TABLE 1 Cold-Rolled Sheet Steel Class Comparison

	Exposed	Unexposed
Major imperfections:		
Cut lengths	Mill rejects	Mill rejects
Coils	Purchaser accepts within the manufacturer's published standards (policy)	Purchaser accepts within the manufacturer's published standards (policy)
Minor imperfections:		
Cut lengths	Mill rejections repetitive imperfections. May contain random imperfections which the purchaser accepts within the manufacturer's published standards (policy)	Purchaser accepts all minor imperfections
Coils	Purchaser accepts within the manufacturer's published standards (policy)	Purchaser accepts all minor imperfections
Finish	Matte unless otherwise specified	Purchaser accepts all finishes
Special oils	May be specified	May not be specified
Thickness, width and length tolerance:		
Standard	Will be met	Will be met
Restricted	May be specified	May not be specified
Flatness tolerance:		
Standard	Will be met	Will be met (temper rolled) Not guaranteed—normally within twice standard (annealed last)
Restricted Squareness	May be specified	May not be specified
Coil wraps	Purchaser accepts within the manufacturer's published standards (policy)	Purchaser accepts all
Coil welds	Purchaser accepts within the manufacturer's published standards (policy)	Purchaser accepts within the manufacturer's published standards (policy)
Outside inspection	May be specified	May not be specified
Special testing	May be specified	May not be specified

5.3.1 Non-killed steels such as capped or rimmed steels are not technologically suited to product analysis due to the nonuniform character of their chemical composition and therefore, the tolerances in Table 2 do not apply. Product analysis is appropriate on these types of steel only when misapplication is apparent or for copper when copper steel is specified.

5.3.2 For steels other than non-killed (capped or rimmed), product analysis may be made by the purchaser. The chemical analysis shall not vary from the limits specified by more than the amounts in Table 2. The several determinations of any element in a cast shall not vary both above and below the specified range.

5.4 *Sampling for Product Analysis*:

5.4.1 To indicate adequately the representative composition of a cast by product analysis, it is general practice to select samples to represent the steel, as fairly as possible, from a minimum number of pieces as follows: 3 pieces for lots up to 15 tons incl, and 6 pieces for lots over 15 tons. (See Practice E 59.)

5.4.2 When the steel is subject to tension test requirements, samples for product analysis may be taken either by drilling entirely through the used tension test specimens themselves, or as covered in 5.4.3.

5.4.3 When the steel is not subject to tension test requirements, the samples for analysis must be taken by milling or drilling entirely through the sheet in a sufficient number of places so that the samples are representative of the entire sheet or strip. The sampling may be facilitated by folding the sheet both ways, so that several samples may be taken at one drilling. Steel subjected to certain heating operations by the purchaser may not give chemical analysis results that properly represent its original composition. Therefore users must analyze chips taken from the steel in the condition in which it is received from the steel manufacturer.

TABLE 2 Tolerances for Product Analysis

Element	Limit, or Maximum of Specified Element, %	Tolerance	
		Under Minimum Limit	Over Maximum Limit
Carbon	to 0.15 incl	0.02	0.03
	over 0.15 to 0.40 incl	0.03	0.04
	over 0.40 to 0.80 incl	0.03	0.05
	over 0.80	0.03	0.06
Manganese	to 0.60 incl	0.03	0.03
	over 0.60 to 1.15 incl	0.04	0.04
	over 1.15 to 1.65 incl	0.05	0.05
Phosphorus		. . .^A	0.01
Sulfur		. . .^A	0.01
Silicon	to 0.30 incl	0.02	0.03
	over 0.30 to 0.60 incl	0.05	0.05
Copper		0.02	. . .^A
Nickel	to 1.00 incl	. . .^A	0.03
Chromium	to 0.90 incl	. . .^A	0.04
Molybdenum	to 0.20 incl	. . .^A	0.01
Vanadium	to 0.10 incl	0.01^B	0.01^B
Columbium (Niobium)	to 0.10 incl	0.01^B	0.01^B
Titanium	to 0.15 incl	0.01^A	0.01^B
Aluminum	to 0.10 incl	0.03^C	. . .^A
Nitrogen	to 0.030 incl	0.005	0.005

^A Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

^B If the minimum of the range is 0.01%, the under tolerance is 0.005%.

^C If the minimum of the range is 0.01%, the under tolerance is 0.005% and if the minimum of the range is 0.02%, the under tolerance is 0.01%.

5.5 *Specimen Preparation*—Drillings or chips must be taken without the application of water, oil, or other lubricant, and must be free of scale, grease, dirt, or other foreign substances. They must not be overheated during cutting to the extent of causing decarburization. Chips must be well mixed and those too coarse to pass a No. 10 sieve or too fine to remain on a No. 30 sieve are not suitable for proper analysis. Sieve size numbers are in accordance with Specification E 11.

5.6 *Test Methods*—In case a referee analysis is required and agreed upon to resolve a dispute concerning the results of a chemical analysis, the procedure of performing the referee analysis must be in accordance with the latest issue of Test Methods, Practices and Terminology A 751, unless otherwise agreed upon between the manufacturer and the purchaser.

6. Mechanical Properties

6.1 The mechanical property requirements, number of specimens, and test locations and specimen orientation shall be in accordance with the applicable product specification.

6.2 Unless otherwise specified in the applicable product specification, test specimens must be prepared in accordance with Test Methods and Definitions A 370.

6.3 Mechanical tests shall be conducted in accordance with Test Methods and Definitions A 370.

6.4 Bend tests where required shall be conducted in compliance with Test Method E 290.

6.5 To determine conformance with the product specification, a calculated value should be rounded to the nearest 1 ksi tensile strength and yield point or yield strength, and to the nearest unit in the right hand place of figures used in expressing the limiting value for other values in accordance with the rounding off method given in Practice E 29.

6.6 Structural sheet steels are commonly fabricated by cold bending. There are many interrelated factors that affect the ability of a given steel to cold form over a given radius under shop conditions. These factors include thickness, strength level, degree of restraint, relationship to rolling direction, chemistry and microstructure. Each of the appropriate product specifications lists in the appendix the suggested minimum specifications lists in the appendix the suggested minimum inside radius for cold bending. These radii should be used as minima for 90° bends. They presuppose "hard way" bending (bend axis parallel to rolling direction) and reasonably good shop forming practices. Where possible, the use of larger radii or "easy way" bends are recommended for improved performance.

6.7 Fabricators should be aware that cracks may initiate upon bending a sheared or burned edge. This is not considered to be a fault of the steel but is rather a function of the induced cold-work or heat-affected zone.

7. General Requirements for Delivery

7.1 The products covered by this specification are produced to inch-pound or metric decimal thickness only and the appropriate thickness tolerances apply.

7.2 Steel may be produced as ingot-cast or strand-cast. When different grades of strand-cast steel are sequentially cast, identification and separation of the transition material is required.

8. Dimensions, Tolerances, and Allowances

8.1 Dimensions, tolerances, and allowances applicable to products covered by this specification are contained in Tables 3-25 [Annex A1, Tables A1.1-A1.20]. The appropriate tolerance tables shall be identified in each individual specification.

8.2 *Flatness Tolerances:*

8.2.1 Standard flatness tolerances are contained in Table 15 and Table 16 for hot-rolled sheet and Table 25 for cold-rolled sheet.

8.2.2 Two alternative methods for flatness determination are the use of I-units and percent steepness. These methods are explained in Appendix X5.

8.2.2.1 The use of I-units or percent steepness as a flatness standard is subject to negotiation between the purchaser and the producer.

8.2.2.2 Measurement techniques for I-units and percent steepness and rejection limits are subject to negotiation between the purchaser and the producer.

9. Finish and Condition

9.1 Hot-rolled sheet has a surface with an oxide or scale resulting from the hot-rolling operation. The oxide or scale can be removed by pickling or blast cleaning when required for press-work operations or welding. Hot-rolled and hot-rolled descaled sheet is not generally used for exposed parts where surface is of prime importance.

9.1.1 Hot-rolled sheet can be supplied with mill edges or cut edges as specified. Mill edges are the natural edges resulting from the hot-rolling operation. They do not conform to any particular contour. They may also contain some edge imperfections, the more common types of which are cracked edges, thin edges (feather), and damaged edges due to handling or processing and which should not extend in beyond the ordered width. These edge conditions are detrimental where joining of the mill edges by welding is practiced. When the purchaser intends to shear or to blank, a sufficient width allowance should be made when purchasing to ensure obtaining the desired contour and size of the pattern sheet. The manufacturer may be consulted for guidance. Cut edges are the normal edges which result from the shearing, slitting, or trimming of mill-edge sheet.

9.1.1.1 The ends of plain hot-rolled mill- edge coils are irregular in shape and are referred to as uncropped ends. Where such ends are not acceptable, the purchaser's order should so specify. Processed coils such as pickled or blast cleaned are supplied with square-cut ends.

9.2 Cold-rolled carbon sheet (exposed) is intended for those applications where surface appearance is of primary importance. This class will meet requirements for controlled surface texture, surface quality, and flatness. It is normally processed by the manufacturer to be free of stretcher strain and fluting. Subsequent user roller leveling immediately before fabrication will minimize strain resulting from aging.

9.2.1 Cold-rolled carbon sheet, when ordered for exposed applications, can be supplied in the following finishes:

9.2.1.1 Matte finish is a dull finish, without luster, produced by rolling on rolls that have been roughened by mechanical or chemical means to various degrees of surface texture depending upon application. With some surface preparation matte finish is suitable for decorative painting. It is not generally recommended for bright plating.

9.2.1.2 Commercial bright finish is a relatively bright finish having a surface texture intermediate between that of matte and luster finish. With some surface preparation commercial bright finish is suitable for decorative painting or certain plating applications. If sheet is deformed in fabrication the surface may roughen to some degree and areas so affected will require surface preparation to restore surface texture to that of the undeformed areas.

9.2.1.3 Luster finish is a smooth bright finish produced by rolling on ground rolls and is suitable for decorative painting or plating with additional special surface preparation by the user. The luster may not be retained after fabrication; therefore, the formed parts will require surface preparation to make them suitable for bright plating.

9.3 Cold-rolled carbon sheet, when intended for unexposed applications, is not subject to limitations on degree and frequency of surface imperfections, and restrictions on texture and mechanical properties are not applicable. When ordered as "annealed last," the product will have coil breaks and a tendency toward fluting and stretcher straining. Unexposed

TABLE 3 List of Tables for Dimensions, Tolerances, and Allowances

Carbon[A] and High-Strength Low-Alloy Steel

Dimensions	Table No.			
	Hot-Rolled Sheet		Cold-Rolled Sheet	
	Inch-Pound Units	SI Units	Inch-Pound Units	SI Units
Camber tolerances	12	A1.9	12, 24	A1.9, A1.19
Diameter tolerances of sheared circles	11	A1.8	11	A1.8
Flatness tolerances	15, 16	A1.12, A1.13	25	A1.20
Length tolerances	10	A1.7	21, 22	A1.16, A1.17
Out-of-square tolerances	13	A1.10	13	A1.10
Restricted Squareness tolerances	14	A1.11	14	A1.11
Thickness tolerances	4, 5, 6, 7	A1.1, A1.2, A1.3, A1.4	17, 18, 19, 20	A1.14, A1.15
Width tolerances of cut edge	9	A1.6	9, 23	A1.6, A1.18
Width tolerances of mill edge	8	A1.5	...	

[A] Tolerances for hot-rolled carbon sheet steel with 0.25 % maximum carbon, cast or heat analysis.

TABLE 4 Standard Thickness Tolerances for Hot-Rolled Sheet (Carbon Steel)—3/8-in. (Cut Edge) and 1/4-in. (Mill Edge) Minimum Edge Distance (Coils and Cut Lengths, Including Pickled)

NOTE 1—Thickness is measured at any point across the width not less than 3/8 in. from a cut edge and not less than 1/4 in. from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2—The specified thickness range captions also apply when sheet is specified to a nominal thickness, and the tolerances are divided equally, over and under.

NOTE 3—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

Specified Width, in.	Thickness Tolerances Over, in., No Tolerance Under					
	Specified Minimum Thickness, in.					
	0.031 to 0.051, incl	Over 0.051 to 0.057, incl	Over 0.057 to 0.071, incl	Over 0.071 to 0.098, incl	Over 0.098 to 0.180, excl	0.180 to 0.230, excl
12 to 20 incl	0.010	0.010	0.012	0.012	0.014	0.014
Over 20 to 40 incl	0.010	0.010	0.012	0.014	0.014	0.016
Over 40 to 48 incl	0.010	0.012	0.012	0.014	0.016	0.018
Over 48 to 60 incl	. . .[A]	0.012	0.014	0.014	0.016	[B]
Over 60 to 72 incl	. . .[A]	0.014	0.014	0.016	0.016	[B]
Over 72	. . .[A]	. . .[A]	. . .[A]	0.016	0.016	[B]

[A] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.
[B] Product not available in this size range.

TABLE 5 Restricted Thickness Tolerances for Hot-Rolled Sheet (Carbon Steel)—5/8-in. (Cut Edge) and 1-in. (Mill Edge) Minimum Edge Distance (Coils and Cut Lengths, Including Pickled)

NOTE 1—Thickness is measured at any point across the width not less than 5/8 in. from a cut edge and not less than 1 in. from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2—The specified thickness range captions also apply when sheet is specified to a nominal thickness, and the tolerances are divided equally, over and under.

NOTE 3—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 4—This table was constructed by multiplying the values in the standard table by 0.75 and rounding to 3 decimal places using standard ASTM practice.

Specified Width, in.	Thickness Tolerances Over, in., No Tolerance Under					
	Specified Minimum Thickness, in.					
	0.031 to 0.051, incl	Over 0.051 to 0.057, incl	Over 0.057 to 0.071, incl	Over 0.071 to 0.098, incl	Over 0.098 to 0.180, excl	0.180 to 0.230, excl
12 to 20 incl	0.008	0.008	0.009	0.009	0.010	0.010
Over 20 to 40, incl	0.008	0.008	0.009	0.010	0.010	0.012
Over 40 to 48, incl	0.008	0.009	0.009	0.010	0.012	0.014
Over 48 to 60, incl	. . .[A]	0.009	0.010	0.010	0.012	[B]
Over 60 to 72, incl	. . .[A]	0.009	0.010	0.012	0.012	[B]
Over 72	. . .[A]	. . .[A]	0.010	0.012	0.012	[B]

[A] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.
[B] Product not available in this size range.

cold-rolled sheet may contain more surface imperfections than exposed cold-rolled sheet because steel applications, processing procedures, and inspection standards are less stringent.

9.4 Cold-rolled high-strength low-alloy sheet is supplied with a matte finish, unless otherwise specified.

9.5 The cold-rolled products covered by this specification are furnished with cut edges and square cut ends, unless otherwise specified.

9.6 *Oiling*:

9.6.1 Plain hot-rolled sheet is customarily furnished not oiled. Oiling must be specified, when required.

9.6.2 Hot-rolled pickled or descaled sheet is customarily furnished oiled. If the product is not to be oiled, it must be so specified since the cleaned surface is prone to rusting.

9.6.3 Cold-rolled products covered by this specification can be furnished oiled or not oiled as specified.

9.7 Sheet steel in coils or cut lengths may contain surface imperfections that can be removed with a reasonable amount of metal finishing by the purchaser.

10. Workmanship

10.1 Cut lengths shall have a workmanlike appearance and shall not have imperfections of a nature or degree for the product, the grade, class, and the quality ordered that will be detrimental to the fabrication of the finished part.

10.2 Coils may contain some abnormal imperfections that render a portion of the coil unusable since the inspection of coils does not afford the producer the same opportunity to remove portions containing imperfections as in the case with cut lengths.

10.3 *Surface Conditions*:

TABLE 6 Standard Thickness Tolerances for Hot-Rolled Sheet (High-Strength, Low-Alloy Steel)—3/8-in. (Cut Edge) and 3/4-in. (Mill Edge) Minimum Edge Distance (Coils and Cut Lengths, Including Pickled)

NOTE 1—Thickness is measured at any point across the width not less than 3/8 in. from a cut edge and not less than 3/4 in. from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2—The specified thickness range captions also apply when sheet is specified to a nominal thickness, and the tolerances are divided equally, over and under.

NOTE 3—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

Specified Width, in.	Thickness Tolerances, Over, in., No Tolerance Under						
	Specified Minimum Thickness, in.						
	0.031 to 0.051, incl	Over 0.051 to 0.059, incl	Over 0.059 to 0.070, incl	Over 0.070 to 0.082, incl	Over 0.082 to 0.098, incl	Over 0.098 to 0.180, excl	0.180 to 0.230, excl
12 to 15, incl	0.010	0.012	0.012	0.012	0.012	0.014	0.014
Over 15 to 20, incl	0.010	0.012	0.014	0.014	0.014	0.016	0.016
Over 20 to 32, incl	0.012	0.012	0.014	0.014	0.014	0.016	0.018
Over 32 to 40, incl	0.012	0.012	0.014	0.014	0.016	0.016	0.018
Over 40 to 48, incl	0.012	0.014	0.014	0.014	0.016	0.020	0.020
Over 48 to 60, incl	. . .[A]	0.014	0.014	0.014	0.016	0.020	[B]
Over 60 to 72, incl	. . .[A]	. . .[A]	0.016	0.016	0.018	0.022	[B]
Over 72 to 80, incl	. . .[A]	. . .[A]	. . .[A]	0.016	0.018	0.024	[B]
Over 80	. . .[A]	. . .[A]	. . .[A]	. . .[A]	0.020	0.024	[B]

[A] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.
[B] Product not available in this size range.

TABLE 7 Restricted Thickness Tolerances for Hot-Rolled Sheet (High-Strength, Low-Alloy Steel)—3/8-in. (Cut Edge) and 1-in. (Mill Edge) Minimum Edge Distance (Coils and Cut Lengths, Including Pickled)

NOTE 1—Thickness is measured at any point across the width not less than 3/8 in. from a cut edge and not less than 1 in. from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2—The specified thickness tolerance range captions also apply when sheet is specified to a nominal thickness, and the tolerances are divided equally, over and under.

NOTE 3—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 4—This table was constructed by multiplying the values in the standard table by 0.75 and rounding to 3 places using standard ASTM practice.

Specified Width, in.	Thickness Tolerances All Over, in., No Tolerance Under						
	Specified Minimum Thickness, in.						
	0.031 to 0.051, incl	Over 0.051 to 0.059, incl	Over 0.059 to 0.070, incl	Over 0.070 to 0.082, incl	Over 0.082 to 0.098, incl	Over 0.098 to 0.180, excl	0.180 to 0.230, excl
12 to 15, incl	0.008	0.009	0.009	0.009	0.009	0.010	0.010
Over 15 to 20, incl	0.008	0.009	0.010	0.010	0.010	0.012	0.012
Over 20 to 32, incl	0.009	0.009	0.010	0.010	0.010	0.012	0.014
Over 32 to 40, incl	0.009	0.009	0.010	0.010	0.012	0.012	0.014
Over 40 to 48, incl	0.009	0.010	0.010	0.010	0.012	0.015	0.015
Over 48 to 60, incl	. . .[A]	0.010	0.010	0.010	0.012	0.015	[B]
Over 60 to 72, incl	. . .[A]	. . .[A]	0.012	0.012	0.014	0.016	[B]
Over 72 to 80, incl	. . .[A]	. . .[A]	. . .[A]	0.012	0.014	0.018	[B]
Over 80	. . .[A]	. . .[A]	. . .[A]	. . .[A]	0.015	0.018	[B]

[A] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.
[B] Product not available in this size range.

10.3.1 Exposed cold-rolled sheet is intended for applications where surface appearance is of primary importance, that is, exposed applications. Unexposed or annealed cold-rolled sheet is intended for applications where surface appearance is not of primary importance, that is, unexposed applications.

10.3.2 Cut lengths for exposed applications shall not include individual sheets having major surface imperfections (holes, loose slivers, and pipe) and repetitive minor surface imperfections. Cut lengths may contain random minor surface imperfections that can be removed with a reasonable amount of metal finishing by the purchaser. These imperfections shall be acceptable to the purchaser within the manufacturer's published standards.

10.3.3 For coils for exposed applications, it is not possible to remove the surface imperfections listed in 10.3.2. Coils will contain such imperfections which shall be acceptable to the purchaser within the manufacturer's published standards. Coils contain more surface imperfections than cut lengths because

TABLE 8 Width Tolerances[A] of Hot-Rolled Mill Edge Sheet (Carbon and High-Strength Low-Alloy Steel)
(Coils and Cut Lengths, Including Pickled)

Specified Width, in.	Tolerances Over Specified Width, in. No Tolerance Under
Carbon	
12 to 14 incl	7/16
Over 14 to 17 incl	1/2
Over 17 to 19 incl	9/16
Over 19 to 21 incl	5/8
Over 21 to 24 incl	11/16
Over 24 to 26 incl	13/16
Over 26 to 30 incl	15/16
Over 30 to 50 incl	1 1/8
Over 50 to 78 incl	1 1/2
Over 78	1 5/8
High-Strength Low-Alloy	
12 to 14 incl	7/16
Over 14 to 17 incl	1/2
Over 17 to 19 incl	9/16
Over 19 to 21 incl	5/8
Over 21 to 24 incl	11/16
Over 24 to 26 incl	13/16
Over 26 to 28 incl	15/16
Over 28 to 35 incl	1 1/8
Over 35 to 50 incl	1 1/4
Over 50 to 60 incl	1 1/2
Over 60 to 65 incl	1 5/8
Over 65 to 70 incl	1 3/4
Over 70 to 80 incl	1 7/8
Over 80	2

[A] The above tolerances do not apply to the uncropped ends of mill edge coils (10.1.1.1).

TABLE 9 Width Tolerances of Hot-Rolled Cut Edge Sheet and Cold-Rolled Sheet (Carbon and High-Strength Low-Alloy Steel)
(Not Resquared, Coils and Cut Lengths, Including Pickled)

Specified Width, in.	Tolerances Over Specified Width, in. No Tolerance Under
Over 12 to 30 incl	1/8
Over 30 to 48 incl	3/16
Over 48 to 60 incl	1/4
Over 60 to 80 incl	5/16
Over 80	3/8

TABLE 10 Length Tolerances of Hot-Rolled Sheet (Carbon and High-Strength Low-Alloy Steel)
(Cut Lengths Not Resquared, Including Pickled)

Specified Length, in.	Tolerances Over Specified Length, in. No Tolerance Under
To 15 incl	1/8
Over 15 to 30 incl	1/4
Over 30 to 60 incl	1/2
Over 60 to 120 incl	3/4
Over 120 to 156 incl	1
Over 156 to 192 incl	1 1/4
Over 192 to 240 incl	1 1/2
Over 240	1 3/4

TABLE 11 Diameter Tolerances of Circles Sheared from Hot-Rolled (Including Pickled) and Cold-Rolled Sheet (Over 12 in. Width) (Carbon and High-Strength Low-Alloy Steel)

Specified Thickness,[A] in.	Tolerances Over Specified Diameter, in. (No Tolerances Under)		
	Under 30	Over 30 to 48 incl	Over 48
0.044 to 0.057 incl	1/16	1/8	3/16
Over 0.057 to 0.098 incl	3/32	5/32	7/32
Over 0.098	1/8	3/16	1/4

[A] 0.071 in. minimum thickness for hot-rolled high-strength low-alloy steel sheet.

TABLE 12 Camber Tolerances[A] for Hot-Rolled (Including Pickled) and Cold-Rolled Sheet (Over 12 in. Width) (Carbon and High-Strength Low-Alloy Steel)
(Cut Lengths, not Resquared)

NOTE 1—Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straightedge.

Cut Length, ft	Camber Tolerances, in.
To 4 incl	1/8
Over 4 to 6 incl	3/16
Over 6 to 8 incl	1/4
Over 8 to 10 incl	5/16
Over 10 to 12 incl	3/8
Over 12 to 14 incl	1/2
Over 14 to 16 incl	5/8
Over 16 to 18 incl	3/4
Over 18 to 20 incl	7/8
Over 20 to 30 incl	1 1/4
Over 30 to 40 incl	1 1/2

[A] The camber tolerance for coils is 1 in. in any 20 ft.

the producer does not have the same opportunity to sort portions containing such imperfections as is possible with cut lengths.

10.3.4 Cut lengths for unexposed applications shall not include individual sheets having major surface imperfections such as holes, loose slivers, and pipe. In addition, unexposed cut lengths can be expected to contain more minor imperfections such as pits, scratches, sticker breaks, edge breaks, pinchers, cross breaks, roll marks, and other surface imperfections than exposed. These imperfections shall be acceptable to the purchaser without limitation.

10.3.5 For coils for unexposed applications, it is not possible to remove the surface imperfections listed in 10.3.4. Coils will contain surface imperfections that are normally not repairable. Minor imperfections shall be acceptable to the purchaser within the manufacturer's published standards. Unexposed coils contain more surface imperfections than exposed coils.

11. Retests and Resampling

11.1 *Retests*:

11.1.1 Unless otherwise prohibited by the product specification, retests are permitted under the following circumstances:

11.1.1.1 If any test specimen shows defective machining or develops flaws, it must be discarded and another specimen substituted.

11.1.1.2 If the percent elongation of any test specimen is less than that specified and any part of the fracture is more than

TABLE 13 Out-of-Square Tolerances of Hot-Rolled Cut-Edge (Including Pickled) and Cold-Rolled Sheet (Over 12 in. Width) (Carbon and High-Strength, Low-Alloy Steel)
(Cut Lengths Not Resquared)

Out-of-square is the greatest deviation of an end edge from a straight line at right angle to a side and touching one corner. It is also obtained by measuring the difference between the diagonals of the cut length. The out-of-square deviation is one half of that difference. The tolerance for all thicknesses and all sizes is 1/16 in./6 in. of width or fraction thereof.

TABLE 14 Restricted Squareness Tolerances of Hot-Rolled (Including Pickled) and Cold-Rolled Sheet (Over 12 in. Width) (Carbon and High-Strength, Low-Alloy Steel)
(Cut Lengths)

When cut lengths are specified resquared, the width and the length are not less than the dimensions specified. The individual tolerance for over-width, over-length, camber, or out-of-square should not exceed 1/16 in. up to and including 48 in. in width and up to and including 120 in. in length. For cut lengths wider or longer, the applicable tolerance is ⅛ in.

TABLE 15 Flatness Tolerances^A of Temper Rolled or Pickled Hot-Rolled Sheet Cut Lengths^B (Carbon and High-Strength, Low-Alloy Steel)

Specified Minimum Thickness, in.	Specified Width, in.	Flatness Tolerances,^C in. Specified Yield Strength, min, ksi Under 45	45 to 50^D,E
0.031 to 0.057 incl	over 12 to 36 incl	½	¾
	over 36 to 60 incl	¾	1⅛
	over 60	1	. . .
0.057 to 0.180 excl	over 12 to 60 incl	½	¾
	over 60 to 72 incl	¾	1⅛
	over 72	1	1½
0.180 to 0.230 excl	over 12 to 48 incl	½	¾

^A The above table also applies to lengths cut from coils by the consumer when adequate flattening operations are performed.
^B Application of this table to product in coil form is not appropriate unless the coil has been rolled out and adequately flattened with all coil set removed.
^C Maximum deviation from a horizontal flat surface.
^D Tolerances for steels with specified minimum yield strength in excess of 50 ksi are subject to negotiation.
^E 0.071 minimum thickness of HSLA.

¾ in. [20 mm] from the center of the gage length of a 2-in. [50 mm] specimen or is outside the middle half of the gage length of an 8-in. [200 mm] specimen, as indicated by scribe scratches marked on the specimen before testing, a retest is allowed.

11.1.13 If a bend specimen fails, due to conditions of bending more severe than required by the specification, a retest is permitted either on a duplicate specimen or on a remaining portion of the failed specimen.

11.2 *Resampling:*

11.2.1 Unless otherwise prohibited by the product specification, resampling is permitted under the following circumstances and using the following practices:

11.2.1.1 If the results of the an original tensile specimen are within 2 ksi (14 MPa) of the required tensile properties, resampling is permitted. The new sample shall be taken from the material in question. If the results of the this new specimen meet the specified requirements, the lot will be accepted.

TABLE 16 Flatness Tolerances^A of Non-Processed Hot Rolled Sheet Cut Lengths^B (Carbon and High-Strength, Low-Alloy Steel)

Specified Minimum Thickness, in.	Specified Width, in.	Flatness Tolerances,^C in. Specified Yield Strength, min, ksi Under 45	45 to 50^D,E
0.031 to 0.057 incl	over 12 to 36 incl	1½	2¼
	over 36 to 60 incl	2¼	3⅜
	over 60	3	. . .
over 0.057 to 0.180 excl	over 12 to 60 incl	1½	2¼
	over 60 to 72 incl	2¼	3⅜
	over 72	3	4½
0.180 to 0.230 excl	over 12 to 48 incl	1½	2¼

^A The above table also applies to lengths cut from coils by the consumer when adequate flattening operations are performed.
^B Application of this table to product in coil form is not appropriate unless the coil has been rolled out and adequately flattened with all coil set removed.
^C Maximum deviation from a horizontal flat surface.
^D Tolerances for steels with specified minimum yield strength in excess of 50 ksi are subject to negotiation.
^E 0.071 minimum thickness of HSLA.

11.2.1.2 If the results of the original tensile specimen are more than 2 ksi (14 MPa) from the required tensile properties, resampling is permitted providing material produced between the location of the original test and the location of the new sample is discarded from the lot to be qualified. Such discarded material shall not be qualified to meet the specification by the new sample. Resampling any lot more than twice shall not be permitted. If the material is resampled, two tests will be required. The first test shall be adjacent to the beginning of the material to be qualified and the second at another location within the lot be qualified. If the results of both resampling test specimens meet the specified requirements, the lot will be accepted. A total of two resampling efforts will be permitted.

12. Inspection

12.1 When purchaser's order stipulates that inspection and tests (except product analyses) for acceptance on the steel be made prior to shipment from the mill, the manufacturer shall afford the purchaser's inspector all reasonable facilities to satisfy him that the steel is being produced and furnished in accordance with the specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operation.

13. Rejection and Rehearing

13.1 Unless otherwise specified, any rejection shall be reported to the manufacturer within a reasonable time after receipt of material by the purchaser.

13.2 Material that is reported to be defective subsequent to the acceptance at the purchaser's works shall be set aside, adequately protected, and correctly identified. The manufacturer shall be notified as soon as possible so that an investigation may be initiated.

13.3 Samples that are representative of the rejected material shall be made available to the manufacturer. In the event that the manufacturer is dissatisfied with the rejection, he may request a rehearing.

TABLE 17 Standard Thickness Tolerances for Cold-Rolled Sheet (Carbon and High-Strength, Low-Alloy Steel)[A]—⅜-in. Minimum Edge Distance (Coils and Cut Lengths Over 12 in. in Width)

NOTE 1—Thickness is measured at any point across the width not less than ⅜ in. from a side edge.

NOTE 2—The specified thickness range captions also apply when sheet is specified to a nominal thickness, and the tolerances are divided equally, over and under.

NOTE 3—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindal shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

Specified Width, in.	Thickness Tolerances, Over, in., No Tolerance Under Specified Minimum Thickness, in.						
	To 0.014, excl	0.014 to 0.019, incl	Over 0.019[A] to 0.039 incl	Over 0.039 to 0.057, incl	Over 0.057 to 0.071, incl	Over 0.071 to 0.098, incl	Over 0.098 to 0.142, incl
12 to 15, incl	0.002	0.004	0.006	0.008	0.010	0.010	0.010
Over 15 to 72, incl	0.002	0.004	0.006	0.008	0.010	0.010	0.012
Over 72	. . .[B]	. . .[B]	0.006	0.008	0.010	0.012	0.014

[A] Minimum Thickness, 0.021 in. for high-strength, low-alloy.

[B] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE 18 Restricted Thickness Tolerances for Cold-Rolled Sheet (Carbon and High-Strength, Low-Alloy Steel)[A]—1-in. Minimum Edge Distance (Coils and Cut Lengths Over 12 in. in Width)

NOTE 1—Thickness is measured at any point across the width not less than 1 in. from a side edge.

NOTE 2—The specified thickness range captions also apply when sheet is specified to a nominal thickness, and the tolerances are divided equally, over and under.

NOTE 3—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindal shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 4—This table was constructed by multiplying the values in the standard table by 0.50 and rounding to 3 places using standard ASTM practice.

Specified Width, in.	Thickness Tolerances, Over, in., No Tolerance Under Specified Minimum Thickness, in.						
	To 0.014, excl	0.014 to 0.019, incl	Over 0.019[A] to 0.039, incl	Over 0.039 to 0.057, incl	Over 0.057 to 0.071, incl	Over 0.071 to 0.098, incl	Over 0.098 to 0.142, incl
12 to 15, incl	0.001	0.002	0.003	0.004	0.005	0.005	0.005
Over 15 to 72, incl	0.001	0.002	0.003	0.004	0.005	0.005	0.006
Over 72	. . .[B]	. . .[B]	0.003	0.004	0.005	0.006	0.007

[A] Minimum Thickness, 0.021 in. for high-strength, low-alloy.

[B] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE 19 Standard Thickness Tolerances for Cold-Rolled Sheet (Carbon and High-Strength, Low-Alloy Steel)[A]—⅜ in. Minimum Edge Distance (Coils and Cut Lengths 2 to 12 in. in Width)

NOTE 1—Thickness is measured at any point across the width not less than ⅜ in. from a side edge.

NOTE 2—The specified thickness range captions also apply when sheet is specified to a nominal thickness, and the tolerances are divided equally, over and under.

NOTE 3—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindal shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

Specified Width, in.	Thickness Tolerances Over, in., No Tolerance Under Specified Minimum Thickness, in.				
	To 0.014, excl	0.014 to 0.019, incl	Over 0.019[A] to 0.039, incl	Over 0.039 to 0.057, incl	Over 0.057 to 0.082, incl
To 12, incl	0.002	0.004	0.006	0.008	0.010

[A] Minimum Thickness, 0.021 in. for high-strength, low-alloy.

14. Test Reports and Certification

14.1 When test reports are required by the purchase order or the material specification, the supplier shall report the results of all test required by the material specification and the order.

14.2 When certification is required by the purchase order, the supplier shall furnish a certification that the material has been manufactured and tested in accordance with the requirements of the material specification.

14.3 A signature is not required on test reports or certifications. However, the document shall clearly identify the organization submitting the document. Notwithstanding the absence of a signature, the organization submitting the document is responsible for the content of the document.

14.4 When test reports are required, copies of the original material manufacturer's test report shall be included with any subsequent test report.

14.5 A Material Test Report, Certificate of Inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM

TABLE 20 Restricted Thickness Tolerances for Cold-Rolled Sheet (Carbon and High-Strength, Low-Alloy Steel)^A—½- in. Minimum Edge Distance (Coils and Cut Lengths 2 to 12 in. in Width)

NOTE 1—Thickness is measured at any point across the width not less than ½ in. from a side edge.

NOTE 2—The specified thickness range captions also apply when sheet is specified to a nominal thickness, and the tolerances are divided equally, over and under.

NOTE 3—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindal shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 4—This table was constructed by multiplying the values in the standard table by 0.50 and rounding to 3 places using standard ASTM practice.

Specified Width, in.	Thickness Tolerances Over, in., No Tolerance Under				
	Specified Minimum Thickness, in.				
	To 0.014, excl	0.014 to 0.019, incl	Over 0.019^A to 0.039, incl	Over 0.039 to 0.057, incl	Over 0.057 to 0.082, incl
To 12, incl	0.001	0.002	0.003	0.004	0.005

^A Minimum Thickness, 0.021 in. for high-strength, low-alloy.

TABLE 21 Length Tolerances of Cold-Rolled Sheet (Carbon and High-Strength, Low-Alloy Steel)
(Cut Lengths Over 12 in. in Width, Not Resquared)

Specified Length, in.	Tolerances Over Specified Length, in. No Tolerances Under
Over 12 to 30, incl	⅛
Over 30 to 60, incl	¼
Over 60 to 96, incl	½
Over 96 to 120, incl	¾
Over 120 to 156, incl	1
Over 156 to 192, incl	1¼
Over 192 to 240 incl	1½
Over 240	1¾

TABLE 22 Length Tolerances of Cold-Rolled Sheet (Carbon and High-Strength, Low-Alloy Steel)
(Cut Length Sheets, to 12 in. in Width and 0.014 in. to 0.082 in. in Thickness, Not Resquared)

NOTE 1—This table applies to widths produced by slitting from wider sheet.

Specified Length, in.	Tolerances Over Specified Length, in. No Tolerance Under
24 to 60, incl	½
Over 60 to 120, incl	¾
Over 120 to 240, incl	1

TABLE 23 Width Tolerances for Cold-Rolled Sheet (Carbon and High-Strength, Low-Alloy Steel)^A
(Coils and Cut Lengths to 12 in. Width, Not Resquared, and 0.014 in. to 0.082 in. in Thickness)

Specified Width, in.	Width Tolerance, Plus and Minus, in.
To 6, incl	0.012
Over 6 to 9, incl	0.016
Over 9 to 12, incl	0.032

^A 0.020 in. minimum thickness for high-strength low-alloy.

standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

NOTE 3—The industry definition as invoked here is: EDI is the computer to computer exchange of business information in an agreed upon standard format such as ANSI ASC X12.

TABLE 24 Camber Tolerances of Cold-Rolled Sheet in Coils (Carbon and High-Strength, Low-Alloy Steel)^A
(Coils to 12 in. in Width 0.014 in. to 0.082 in. in Thickness)

NOTE 1—Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straightedge.

NOTE 2—This table applies to widths produced by slitting from wider sheet.

Width, in.	Camber Tolerance
To 12, incl	¼ in. in any 8 ft

^A 0.020 in. minimum thickness for high-strength low-alloy.

TABLE 25 Flatness Tolerances of Cold-Rolled Sheet (Carbon and High-Strength, Low-Alloy Steel)
(Cut Lengths Over 12 in. in Width)

NOTE 1—This table does not apply when product is ordered full hard, to a hardness range, or "annealed last" (dead soft).

NOTE 2—This table also applies to lengths cut from coils by the consumer when adequate flattening measures are performed.

Specified Thickness, in.	Specified Width, in.	Flatness Tolerance,^A in.	
		Specified Yield Point, min, ksi	
		Under 45	45 to 50^B incl.
To 0.044, incl	to 36 incl	⅜	¾
	over 36 to 60 incl	⅝	1⅛
	over 60	⅞	1½
Over 0.044	to 36 incl	¼	¾
	over 36 to 60 incl	⅜	¾
	over 60 to 72 incl	⅝	1⅛
	over 72	⅞	1½

^A Maximum deviation from a horizontal flat surface.
^B Tolerances for high-strength, low-alloy steel with specified minimum yield point in excess of 50 ksi are subject to negotiation.

15. Product Marking

15.1 As a minimum requirement, the material shall be identified by having the manufacturer's name, ASTM designation, weight, purchaser's order number, and material identification legibly stenciled on top of each lift or shown on a tag attached to each coil or shipping unit.

15.2 When specified in the contract or order, and for direct procurement by or direct shipment to the government, marking for shipment in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

15.3 Bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the primary metals subcommittee of the AIAG bar code project team.

16. Packing and Package Marking

16.1 Unless otherwise specified, the sheet shall be packaged and loaded in accordance with Practices A 700.

16.2 When specified in the contract or order, and for direct procurement by or direct shipment to the government, when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

16.3 When coils are ordered, it is customary to specify a minimum or range of inside diameter, maximum outside diameter, and a maximum coil weight, if required. The ability of manufacturers to meet the maximum coil weights depends upon individual mill equipment. When required, minimum coil weights are subject to negotiation.

17. Keywords

17.1 alloy steel sheet; carbon steel sheet; cold rolled steel sheet; general delivery requirements; high strength low alloy steel; hot rolled steel sheet; steel sheet

ANNEX

(Mandatory Information)

A1. PERMISSIBLE VARIATIONS IN DIMENSIONS AND MASS IN SI UNITS

A1.1 Listed in Tables A1.1-A1.20 are permissible variations in dimensions and mass expressed in the International System of Units (SI) terminology.

TABLE A1.1 Standard Thickness Tolerances [Metric] for Hot-Rolled Sheet (Carbon Steel)—10-mm (Cut Edge) and 20-mm (Mill Edge) Minimum Edge Distance (Coils and Cut Lengths, Including Pickled)

NOTE 1—Thickness is measured at any point across the width not less than 10 mm from a cut edge and not less than 20 mm from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2—The specified thickness range captions also apply when sheet is specified to a nominal thickness, and the tolerances are divided equally, over and under.

NOTE 3—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

Specified Width, mm	Thickness Tolerances, Over, mm, No Tolerance Under			
	Specified Minimum Thickness, mm			
	Through 2.0	Over 2.0 to 2.5, incl	Over 2.5 to 4.5, excl	4.5 to 6.0, excl
Over 300 to 600, incl	0.30	0.30	0.35	0.40
Over 600 to 1200, incl	0.30	0.35	0.40	0.45
Over 1200 to 1500, incl	0.35	0.35	0.40	A
Over 1500 to 1800, incl	0.35	0.40	0.40	A
Over 1800	0.35	0.40	0.40	A

A Product not available in this size range.

TABLE A1.2 Restricted Thickness Tolerances [Metric] for Hot-Rolled Sheet (Carbon Steel)—15-mm (Cut Edge) and 25-mm (Mill Edge) Minimum Edge Distance (Coils and Cut Lengths, Including Pickled)

NOTE 1—Thickness is measured at any point across the width not less than 15 mm from a cut edge and not less than 25 mm from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2—The specified thickness range captions also apply when sheet is specified to a nominal thickness, and the tolerances are divided equally, over and under.

NOTE 3—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 4—This table was constructed by multiplying the values in the standard table by 0.75 and rounding to 2 decimal places using standard ASTM practice.

Specified Width, mm	Thickness Tolerances Over, mm, No Tolerance Under			
	Specified Minimum Thickness, mm			
	Through 2.0	Over 2.0 to 2.5, incl	Over 2.5 to 4.5, excl	4.5 to 6.0, excl
Over 300 to 600	0.22	0.22	[illegible]	0.33
Over 600 to 1200, incl	0.22	0.26	[illegible]	0.34
Over 1200 to 1500, incl	0.26	0.26	[illegible]	A
Over 1500 to 1800, incl	0.26	0.30	[illegible]	A
Over 1800	0.26	0.30	[illegible]	A

A Product not available in this size range.

TABLE A1.3 Standard Thickness Tolerances [Metric] for Hot-Rolled Sheet (High-Strength, Low-Alloy Steel)—10-mm (Cut Edge) and 20-mm (Mill Edge) Minimum Edge Distance (Coils and Cut Lengths, Including Pickled)

NOTE 1—Thickness is measured at any point across the width not less than 10 mm from a cut edge and not less than 20 mm from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2—The specified thickness range captions also apply when sheet is specified to a nominal thickness, and the tolerances are divided equally, over and under.

NOTE 3—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

Specified Width, mm	Thickness Tolerances Over, mm, No Tolerance Under			
	Specified Minimum Thickness, mm			
	Through 2.0	Over 2.0 to 2.5, incl	Over 2.5 to 4.5, excl	4.5 to 6.0, excl
Over 300 to 600, incl	[illegible]	0.35	0.40	0.40
Over 600 to 1200, incl	[illegible]	0.40	0.45	0.50
Over 1200 to 1500, incl	[illegible]	0.40	0.50	A
Over 1500 to 1800, incl	[illegible]	0.45	0.55	A
Over 1800 to 2000, incl	[illegible]	0.45	0.60	A
Over 2000	... B	0.50	0.60	A

A Product not available in this size range.

B Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE A1.4 **Restricted Thickness Tolerances of Hot-Rolled Sheet (High-Strength, Low-Alloy Steel)—15-mm (Cut Edge) and 25-mm (Mill Edge) Minimum Edge Distance (Coils and Cut Lengths, Including Pickled)**

NOTE 1—Thickness is measured at any point across the width not less than 15 mm from a cut edge and not less than 25 mm from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2—The specified thickness range captions also apply when sheet is specified to a nominal thickness, and the tolerances are divided equally, over and under.

NOTE 3—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 4—This table was constructed by multiplying the values in the standard table by 0.75 and rounding to 2 decimal places using standard ASTM practice.

Specified Width, mm	Thickness Tolerances Over, mm, No Tolerance Under			
	Specified Minimum Thickness, mm			
	Through 2.0	Over 2.0 to 2.5, incl	Over 2.5 to 4.5, excl	4.5 to 6.0, excl
Over 300 to 600, incl	0.22	0.26	0.30	0.30
Over 600 to 1200, incl	0.26	0.30	0.34	0.38
Over 1200 to 1500, incl	0.26	0.30	0.38	A
Over 1500 to 1800, incl	0.30	0.34	0.41	A
Over 1800 to 2000, incl	0.30	0.34	0.45	A
Over 2000	. . .B	0.38	0.45	A

A Product not available in this size range.

B Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE A1.5 **Width Tolerances**A **of Hot-Rolled Mill Edge Sheet (Carbon and High-Strength Low-Alloy Steel)**
(Coils and Cut Lengths, Including Pickled)

Specified Width, mm		Width Tolerance, Over Only, mm	
Over	Through	Carbon	HSLA
300	600	16	16
600	1200	26	28
1200	1500	32	38
1500	1800	35	45
1800	. . .	48	50

A The above tolerances do not apply to the uncropped ends of mill edge coils (9.1.1.1).

TABLE A1.6 **Width Tolerances of Hot-Rolled Cut Edge Sheet and Cold-Rolled Sheet (Carbon and High-Strength Low-Alloy Steel)**
(Not Resquared Coils and Cut Lengths, Including Pickled)

Specified Width, mm		Width Tolerance, Over Only, mm
Over	Through	
300	600	3
600	1200	5
1200	1500	6
1500	1800	8
1800	. . .	10

TABLE A1.7 **Length Tolerances of Hot-Rolled Sheet (Carbon and High-Strength Low-Alloy Steel)**
(Cut Lengths Not Resquared, Including Pickled)

Specified Length, mm		Length Tolerance, Over Only, mm
Over	Through	
300	600	6
600	900	8
900	1500	12
1500	3000	20
3000	4000	25
4000	5000	35
5000	6000	40
6000	. . .	45

TABLE A1.8 **Diameter Tolerances of Circles from Hot-Rolled (Including Pickled) and Cold-Rolled Sheet (Over 300 mm Width) (Carbon and High-Strength Low-Alloy Steel)**

Specified ThicknessA, mm		Tolerances Over Specified Diameter, mm (No Tolerances Under)		
Over	Through	Diameters, mm		
		Through 600	Over 600 to 1200, incl	Over 1200
. . .	1.5	1.5	3.0	5.0
1.5	2.5	2.5	4.0	5.5
2.5	. . .	3.0	5.0	6.5

A 1.8 mm minimum thickness for hot-rolled high-strength low-alloy steel sheet.

TABLE A1.9 **Camber Tolerances**A **for Hot-Rolled (Including Pickled) and Cold-Rolled Sheet (Over 300 mm Width) (Carbon and High-Strength Low-Alloy Steel)**
(Cut Lengths, Not Resquared)

NOTE 1—Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straightedge.

Cut Length, mm		Camber ToleranceA, mm
Over	Through	
. . .	1200	4
1200	1800	5
1800	2400	6
2400	3000	8
3000	3700	10
3700	4300	13
4300	4900	16
4900	5500	19
5500	6000	22
6000	9000	32
9000	12 200	38

A The camber tolerance for coils is 25.0 mm in any 6000 mm.

TABLE A1.10 Out-of-Square Tolerances of Hot-Rolled Cut-Edge (Including Pickled) and Cold-Rolled Sheet (Over 300 mm Width) (Carbon and High-Strength Low-Alloy Steel) (Cut Lengths Not Resquared)

Out-of-square is the greatest deviation of an end edge from a straight line at right angle to a side and touching one corner. It is also obtained by measuring the difference between the diagonals of the cut length. The out-of-square deviation is one half of that difference. The tolerance for all thicknesses and all sizes is 1.0 mm/100 mm of width or fraction thereof.

TABLE A1.11 Restricted Squareness Tolerances of Hot-Rolled (Including Pickled) and Cold-Rolled Sheet (Over 300 mm Width) (Carbon and High-Strength Low-Alloy Steel) (Cut Lengths)

When cut lengths are specified resquared, the width and the length are not less than the dimensions specified. The individual tolerance for over-width, over-length, camber, or out-of-square should not exceed 1.6 mm up to and including 1200 mm in width and up to and including 3000 mm in length. For cut lengths wider or longer, the applicable tolerance is 3.2 mm.

TABLE A1.12 Flatness Tolerances[A] of Temper Rolled or Pickled Hot-Rolled Sheet Cut Lengths[B] (Carbon and High-Strength Low-Alloy Steel)

Specified Thickness, mm		Specified Width, mm	Flatness Tolerance[C], mm Specified Yield Strength, min, MPa[D]	
Over	Through		Under 310	310 to 345 MPa Yield Point, min, MPa
1.2	1.5	to 900, incl	15	20
		over 900 to 1500, incl	20	30
		over 1500	25	. . .
1.5	4.5	to 1500, incl	15	20
		over 1500 to 1800, incl	20	30
		over 1800	25	40
4.5	6.0 excl	to 1200, incl	15	20

[A] The above table also applies to lengths cut from coils by the consumer when adequate flattening operations are performed.
[B] Application of this table to product in coil form is not appropriate unless the coil has been rolled out and adequately flattened with all coil set removed.
[C] Maximum deviation from a horizontal surface.
[D] Tolerances for high-strength, low-alloy steels with specified minimum yield strength in excess of 345 MPa are subject to negotiation.

TABLE A1.13 Flatness Tolerances[A] of Non-Processed Hot-Rolled Sheet Cut Lengths[B] (Carbon and High-Strength Low-Alloy Steel)

Specified Thickness, mm		Specified Width, mm	Flatness Tolerance[C], mm Specified Yield Strength, min, MPa[D]	
Over	Through		Under 310	310 to 345 MPa Yield Point, min, MPa
1.2	1.5	to 900, incl	45	60
		over 900 to 1500, incl	50	90
		over 1500	75	. . .
1.5	4.5	to 1500, incl	45	60
		over 1500 to 1800, incl	50	90
		over 1800	75	120
4.5	6.0 excl	to 1200, incl	45	60

[A] The above table also applies to lengths cut from coils by the consumer when adequate flattening operations are performed.
[B] Application of this table to product in coil form is not appropriate unless the coil has been rolled out and adequately flattened with all coil set removed.
[C] Maximum deviation from a horizontal surface.
[D] Tolerances for high-strength, low-alloy steels with specified minimum yield strength in excess of 345 MPa are subject to negotiation.

TABLE A1.14 Standard Thickness Tolerances [Metric] for Cold-Rolled Sheet (Carbon and High-Strength, Low-Alloy Steel)[A]—10-mm Minimum Edge Distance

NOTE 1—Thickness is measured at any point across the width not less than 10 mm from a side edge.

NOTE 2—Widths up to and including 300 mm in this table apply to widths produced by slitting from wider sheet.

NOTE 3—The specified thickness range captions also apply when sheet is specified to a nominal thickness, and the tolerances are divided equally, over and under.

NOTE 4—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

Specified Width, mm		Thickness Tolerances Over, mm, No Tolerance Under				
		Specified Minimum Thickness, mm				
Over	Through	Through 0.4	Over 0.4 to 1.0, incl	Over 1.0 to 1.2, incl	Over 1.2 to 2.5, incl	Over 2.5 to 4.0, incl
50	1800	0.10	0.15	0.20	0.25	0.30[B]
1800	2000	. . .[C]	0.15	0.20	0.30	0.35
2000	. . .[C]	. . .[C]	0.30	0.30	0.35	0.40

[A] 0.55-mm minimum thickness for high-strength low-alloy.
[B] Not applicable to widths under 300 mm.
[C] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE A1.15 Restricted Thickness Tolerances of Cold-Rolled Sheet (Carbon and High-Strength, Low-Alloy Steel)[A]—25-mm Minimum Edge Distance

NOTE 1—Thickness is measured at any point across the width not less than 25 mm from a side edge.

NOTE 2—Widths up to and including 300 mm in this table apply to widths produced by slitting from wider sheet.

NOTE 3—The specified thickness range captions also apply when sheet is specified to a nominal thickness, and the tolerances are divided equally, over and under.

NOTE 4—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 5—This table was constructed by multiplying the values in the standard table by 0.50 and rounding to 2 decimal places using standard ASTM practice.

Specified Width, mm		Thickness Tolerances Over, mm, No Tolerance Under				
		Specified Minimum Thickness, mm				
Over	Through	Through 0.4	Over 0.4 to 1.0, incl	Over 1.0 to 1.2, incl	Over 1.2 to 2.5, incl	Over 2.5 to 4.0, incl
50	1800	0.05	0.08	0.10	0.12	0.15[B]
1800	2000	. . .[C]	0.08	0.10	0.15	0.18
2000	. . .[C]	. . .[C]	0.15	0.15	0.15	0.20

[A] 0.55 mm minimum thickness for high-strength low-alloy.
[B] Not applicable to widths under 300 mm.
[C] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE A1.16 Length Tolerances of Cold-Rolled Sheet (Carbon and High-Strength Low-Alloy Steel)
(Cut Lengths Over 300 mm in Width, Not Resquared)

Specified Length, mm		Tolerance Over Specified Length (No Tolerance Under), mm
Over	Through	
300	1500	6
1500	3000	20
3000	6000	35
6000	. . .	45

TABLE A1.17 Length Tolerances of Cold-Rolled Sheet (Carbon and High-Strength Low-Alloy Steel)
(Cut Length Sheets, to 300 mm in Width and 0.35 to 2.0 mm in Thickness, Not Resquared)

NOTE 1—This table applies to widths produced by slitting from wider sheet.

Specified Length, mm		Tolerances Over Specified Length (No Tolerance Under), mm
Over	Through	
600	1500	15
1500	3000	20
3000	6000	25

TABLE A1.18 Width Tolerances for Cold-Rolled Sheet (Carbon and High-Strength Low-Alloy Steel)[A]
(Coils and Cut Lengths to 300 mm in Width, Not Resquared, and 0.35 to 2.0 mm in Thickness)

NOTE 1—This table applies to widths produced by slitting from wider sheet.

Specified Width, mm		Width Tolerance, Over and Under, mm
Over	Through	
50	100	0.3
100	200	0.4
200	300	0.8

[A] 0.50 mm thickness for high-strength low-alloy.

TABLE A1.19 Camber Tolerances of Cold-Rolled Sheet in Coils (Carbon and High-Strength Low-Alloy Steel 0.35[A] to 2.0 mm in Thickness)

NOTE 1—Camber is the greatest deviation of a side edge from a straight line, the measurements being taken on the concave side with a straightedge.

NOTE 2—This table applies to widths produced by slitting from wider sheet.

Width, mm	Camber Tolerances
Through 300, incl	5.0 mm in any 2000 mm

[A] 0.50 mm minimum thickness for high-strength low-alloy.

TABLE A1.20 Flatness Tolerances of Cold-Rolled Sheet (Carbon and High-Strength Low-Alloy Steel)[A]
(Cut Lengths Over 300 mm in Width)

NOTE 1—This table does not apply when product is ordered full hard, to a hardness range or "annealed last" (dead soft).

NOTE 2—This table also applies to lengths cut from coils by the consumer when adequate flattening measures are performed.

NOTE 3—Application of this table to product in coil form is not appropriate unless the coil has been rolled out and adequately flattened with all coil set removed.

Specified Thickness, mm	Specified Width, mm		Flatness Tolerance, mm Specified Yield Point, min, MPa	
	Over	Through	Under 310 MPa	310 to 345 MPa[B]
Through 1.0	. . .	900	10	20
	900	1500	15	30
	1500		20	40
Over 1.0	. . .	900	8	20
	900	1500	10	20
	1500	1800	15	30
	1800	. . .	20	40

[A] Maximum deviation from a horizontal flat surface.

[B] Tolerances for high-strength, low-alloy steel with specified minimum yield point in excess of 345 MPa are subject to negotiation.

APPENDIXES

(Nonmandatory Information)

X1. AGING EFFECTS ON FORMABILITY OF COLD-ROLLED CARBON-STEEL SHEET PRODUCTS

X1.1 Cold-rolled carbon-steel sheet products exhibit maximum formability in the annealed last, or dead-soft, condition. However, many sheet products are not suitable for exposed applications in the dead-soft condition because Luder's lines (sometimes referred to as "stretcher strains" or "fluting") may develop during subsequent forming. This problem is avoided in most cases by temper rolling the sheet after annealing. After temper rolling, however, some sheet products are susceptible to aging. Aging refers to a gradual increase in yield strength and corresponding decrease in ductility during storage after temper rolling. Aging always has a negative effect on formability and, when aging leads to the redevelopment of an upper yield point, can result in renewed susceptibility to fluting.

X1.2 Aging can occur when interstitial solute atoms, carbon or nitrogen, are present in the steel. Solute carbon or nitrogen atoms are those not chemically combined with other elements in the steel (as carbides or nitrides, for example). Over time, these carbon or nitrogen interstitial solute atoms diffuse to crystalline imperfections within the steel and, in so doing, give rise to aging. The extent to which aging occurs depends on the interstitial solute level and the combination of temperature and time to which the steel is exposed after temper rolling. In general, higher interstitial solute levels result in larger strength increases during storage; the rate of aging increases with increasing temperature. As described as follows, the final interstitial solute level and aging characteristics depend on the chemical composition of the steel as well as specific sheet-processing methods used by the steel producer.

X1.3 *Low-Carbon Steels*—In conventional aluminum-killed low-carbon steels, the level of interstitial solute is affected mainly through the formation of aluminum nitride and iron carbides within the steel during processing, which is influenced by the manner in which annealing is performed.

X1.3.1 Many sheet products are annealed in batches of large, tightly wound coils. During heating, any solute nitrogen present in the full-hard sheet combines with aluminum to form aluminum nitride. Subsequent cooling is very slow and allows essentially all of the carbon to precipitate as iron carbide. Final interstitial solute levels are very low and, as a result, batch-annealed low-carbon steels have excellent resistance to aging.

X1.3.1.1 Deep drawing steel (DDS) sheet typically is batch-annealed and has excellent aging resistance. With temper rolling, DDS sheet is suitable for use in many exposed applications with severe forming requirements.

X1.3.2 Cold-rolled low-carbon steels are sometimes processed in a continuous annealing line, in which the full-hard sheet is uncoiled, passed through an annealing furnace, and then rewound in a continuous manner. Heating and cooling rates are much higher than those found in batch annealing. The faster cooling, in particular, results in higher levels of interstitial solute in the product as compared with batch annealing. The manner in which the sheet is cooled can be controlled to minimize the solute carbon level, and temper rolling is effective for reducing fluting tendencies. However, continuous-annealed low-carbon steels are more prone to subsequent aging than batch-annealed steels.

X1.3.2.1 Low-carbon commercial steel (CS) and drawing steel (DS) sheet are available as either batch- or continuous-annealed products, depending on the facilities of a given producer. To minimize aging effects in continuous-annealed products, rotation of stock by fabricating the oldest material first is recommended.

X1.4 *Interstitial-Free Steels*—Interstitial-free steels have essentially no interstitial solutes and, as a result, are nonaging. Processing involves vacuum degassing during refining of the liquid steel, as well as additions of elements that form very stable carbides and nitrides, such as titanium or columbium (niobium). These steps ensure that total interstitial levels are very low, and that the interstitials are all chemically combined (or stabilized) in the form of alloy carbides or nitrides. Interstitial-free steels are nonaging regardless of whether annealing is conducted in a continuous or batch manner.

X1.4.1 Extra-deep drawing steel (EDDS) must be vacuum degassed and stabilized. This nonaging, interstitial-free product is suitable for exposed applications with the most severe forming requirements.

X1.5 *Bake-Hardenable Steels*—Bake-hardenable steels are a special product class with controlled interstitial solute levels and aging behavior. These steels are processed to have moderate aging resistance, to permit forming while the steel is in its most ductile condition. Aging occurs largely during a subsequent thermal treatment (for example, paint-curing), which results in desirable hardening of the final part for better durability.

X1.5.1 Continuous-annealed low-carbon steels can exhibit significant bake-hardening, as well as certain vacuum-degassed and batch-annealed steels.

X2. STANDARD CHEMICAL RANGES AND LIMITS

X2.1 Standard chemical ranges and limits are prescribed for carbon steels in Table X2.1 and Table X2.2.

TABLE X2.1 Standard Steels—Carbon Sheet Steel Compositions

Steel Designation No.	Chemical Composition Limits, %			
	C	Mn	P max	S max
1001	0.01 max	0.35 max	0.030	0.035
1002	0.02 max	0.35 max	0.030	0.035
1003	0.04 max	0.35 max	0.030	0.035
1004	0.02/0.06	0.35 max	0.030	0.035
1005	0.06 max	0.35 max	0.030	0.035
1006A	0.02/0.08	0.45 max	0.030	0.035
1006	0.08 max	0.45 max	0.030	0.035
1007	0.02/0.10	0.50 max	0.030	0.035
1008	0.10 max	0.50 max	0.030	0.035
1009	0.15 max	0.60 max	0.030	0.035
1010	0.08–0.13	0.30–0.60	0.030	0.035
1012	0.10–0.15	0.30–0.60	0.030	0.035
1015	0.12–0.18	0.30–0.60	0.030	0.035
1016	0.12–0.18	0.60–0.90	0.030	0.035
1017	0.14–0.20	0.30–0.60	0.030	0.035
1018	0.14–0.20	0.60–0.90	0.030	0.035
1019	0.14–0.20	0.70–1.00	0.030	0.035
1020	0.17–0.23	0.30–0.60	0.030	0.035
1021	0.17–0.23	0.60–0.90	0.030	0.035
1022	0.17–0.23	0.70–1.00	0.030	0.035
1023	0.19–0.25	0.30–0.60	0.030	0.035
1025	0.22–0.28	0.30–0.60	0.030	0.035
1026	0.22–0.28	0.60–0.90	0.030	0.035
1030	0.27–0.34	0.60–0.90	0.030	0.035
1033	0.29–0.36	0.70–1.00	0.030	0.035
1035	0.31–0.38	0.60–0.90	0.030	0.035
1037	0.31–0.38	0.70–1.00	0.030	0.035
1038	0.34–0.42	0.60–0.90	0.030	0.035
1039	0.36–0.44	0.70–1.00	0.030	0.035
1040	0.36–0.44	0.60–0.90	0.030	0.035
1042	0.39–0.47	0.60–0.90	0.030	0.035
1043	0.39–0.47	0.70–1.00	0.030	0.035
1045	0.42–0.50	0.60–0.90	0.030	0.035
1046	0.42–0.50	0.70–1.00	0.030	0.035
1049	0.45–0.53	0.60–0.90	0.030	0.035
1050	0.47–0.55	0.60–0.90	0.030	0.035
1055	0.52–0.60	0.60–0.90	0.030	0.035
1060	0.55–0.66	0.60–0.90	0.030	0.035
1064	0.59–0.70	0.50–0.80	0.030	0.035
1065	0.59–0.70	0.60–0.90	0.030	0.035
1070	0.65–0.76	0.60–0.90	0.030	0.035
1074	0.69–0.80	0.50–0.80	0.030	0.035
1078	0.72–0.86	0.30–0.60	0.030	0.035
1080	0.74–0.88	0.60–0.90	0.030	0.035
1084	0.80–0.94	0.60–0.90	0.030	0.035
1085	0.80–0.94	0.70–1.00	0.030	0.035
1086	0.80–0.94	0.30–0.50	0.030	0.035
1090	0.84–0.98	0.69–0.90	0.030	0.035
1095	0.90–1.04	0.30–0.50	0.030	0.035
1524	0.18–0.25	1.30–1.65	0.030	0.035
1527	0.22–0.29	1.20–1.55	0.030	0.035
1536	0.30–0.38	1.20–1.55	0.030	0.035
1541	0.36–0.45	1.30–1.65	0.030	0.035
1548	0.43–0.52	1.05–1.40	0.030	0.035
1552	0.46–0.55	1.20–1.55	0.030	0.035

NOTE—When silicon is required, the following ranges and limits are commonly used.

To 1015, excl	0.10 max
1015 to 1025, incl	0.10 max, 0.10–0.25, or 0.15–0.30
Over 1025	0.10–0.25 or 0.15–0.30

TABLE X2.2 Standard Chemical Ranges and Limits

Note 1—The carbon ranges shown in the column headed "Range" apply when the specified maximum limit for manganese does not exceed 1.00 %. When the maximum manganese limit exceeds 1.00 %, add 0.01 to the carbon ranges shown below.

Element	Carbon Steels Only, Cast or Heat Analysis		
	Maximum Specified Element, %	Range	Lowest max
Carbon (see Note)	to 0.15 incl	0.05	0.08
	over 0.15 to 0.30 incl	0.06	
	over 0.30 to 0.40 incl	0.07	
	over 0.40 to 0.60 incl	0.08	
	over 0.60 to 0.80 incl	0.11	
	over 0.80 to 1.35 incl	0.14	
Manganese	to 0.50 incl	0.20	0.40
	over 0.50 to 1.15 incl	0.30	
	over 1.15 to 1.65 incl	0.35	
Phosphorus	to 0.08 incl	0.03	0.030[A]
	over 0.08 to 0.015 incl	0.05	
Sulfur	to 0.08 incl	0.03	0.035[A]
	over 0.08 to 0.15 incl	0.05	
	over 0.15 to 0.23 incl	0.07	
	over 0.23 to 0.33 incl	0.10	
Silicon	to 0.15 incl	0.08	0.10
	over 0.15 to 0.30 incl	0.15	
	over 0.30 to 0.60 incl	0.30	
Copper	When copper is required 0.20 min is commonly specified		

[A] Certain individual specifications provide for lower standard limits for phosphorus and sulfur.

X3. PROCEDURE FOR DETERMINING BREAKAGE ALLOWANCE LEVELS (APPLICABLE TO CARBON STEEL SHEET ONLY)

X3.1 In spite of the many extra precautions exercised in making sheet for drawing purposes, certain manufacturing variables may be encountered, all beyond the manufacturer's reasonable control, which may contribute to breakage in fabrication and must be considered as part of the normal hazard of the purchaser's use. The manufacturer will undertake to establish with the purchaser's concurrence a breakage allowance level.

X3.2 Breakage, for the purpose of this proposal, is defined as unrepairable parts, broken during drawing and classed as scrap. Parts showing laminations, resulting from pipe, may be excluded provided they are separately identified. Broken parts that can be salvaged are not covered in this procedure.

X3.3 This procedure is intended to establish a breakage allowance without the need for reinspection of each broken stamping. It will apply to overall breakage on a given part (as calculated by the method outlined below) in excess of 1 % up to and including 8 %. Inherent variations in steel and normal variables in the stamping operation preclude 100 % satisfactory performance. Therefore, it is accepted that practical perfection is attained when 99 % of the stampings are produced without breakage. When the overall breakage is in excess of 8 %, it is considered to be the result of abnormal stamping conditions, and this method does not apply.

X3.4 When there are two or more suppliers, the recommended procedure for determining a breakage allowance for an identified part is based on the average percentage of breakage of at least 75 % of the blanks run on that part, on one set of dies, during at least one month (3000 piece minimum). The total production of all suppliers used to obtain this 75 % minimum is to be included in the calculation starting with the best performance. The average breakage thus determined shall be considered the allowance for the part.

X3.4.1 *Example:*

Vendor	Parts Produced	Parts Scrap	% Scrap
A	32 466	630	1.94
B	27 856	579	2.08
C	67 120	1477	2.20
D	56 200	1349	2.40
E	40 900	1125	2.75
F	850	60	7.05
11	225 392 total	5220 total	2.32 avg

X3.4.2 Seventy-five percent of 225 392 equals to 169 044; therefore, it is necessary to include the total production of vendors A, B, C, and D (A + B + C + D = total production of 183 642 parts) since the total of A, B, and C is only 127 442, which is less than 75 % of the total. Total production of 183 642 parts (A + B + C + D) with 4035 parts being rejected, results in a percentage allowance of 2.20 %. On this basis, vendors D, E, and F exceed the allowance.

X4. PROCEDURES FOR DETERMINING THE EXTENT OF PLASTIC DEFORMATION ENCOUNTERED IN FORMING OR DRAWING

X4.1 Introduction

X4.1.1 The preferred method for determining plastic strain is the circle grid and forming limit curve. The scribed square and change in thickness methods may also be used to evaluate deformation during the forming of a flat sheet into the desired shape.

X4.2 Circle Grid Method

X4.2.1 The test system employs photographic or electrochemically etched circle patterns on the surface of a sheet metal blank of known "quality" and a forming limit curve for the evaluation of strains developed by forming in press operations. It is useful in the laboratory and in the press room. Selection from the various steels that are commercially available can be done effectively by employing this technique. In addition, corrective action in die or part design to improve performance is indicated.

X4.2.2 The forming limit curve in Fig. X4.1 has been developed from actual measurements of the major (e_1) and associated minor (e_2) strains found in critical areas of production type stampings. Strain combinations that locate below this curve are safe, while those that fail above the curve are critical. For analysis of metal strain on production stampings, one must recognize that day-to-day variations of material, lubrication, and die settings will affect the strain level. To ensure trouble-free press performance a zone below the forming limit curve bounded by the dashed and solid lines is designated as the "safety band." Therefore, strain combinations falling below the dashed lines should not exceed the forming limit curve in normal production operations. The left of zero portion of the curve defines the limiting biaxial tension-compression strain combination while the right side defines the forming limit curve. Because the production stampings used to develop for forming limit curve represented all qualities of low-carbon light-gage sheet steel, this single forming limit curve can be used successfully for these products.

X4.2.3 The circle grid method can also be used for other low-carbon sheet categories if the following adjustments to the forming limit curve are made:

X4.2.3.1 *Material Thickness*—As the metal thickness increases the forming limit curve shifts upwards in a parallel manner, 0.2 % (e_1) strain for each 0.025-mm increase in metal thickness above 0.75 mm.

X4.2.3.2 *Material Properties*—When material properties are considerably different from that of conventional low-carbon sheet steel (for example, higher strength-low ductility),

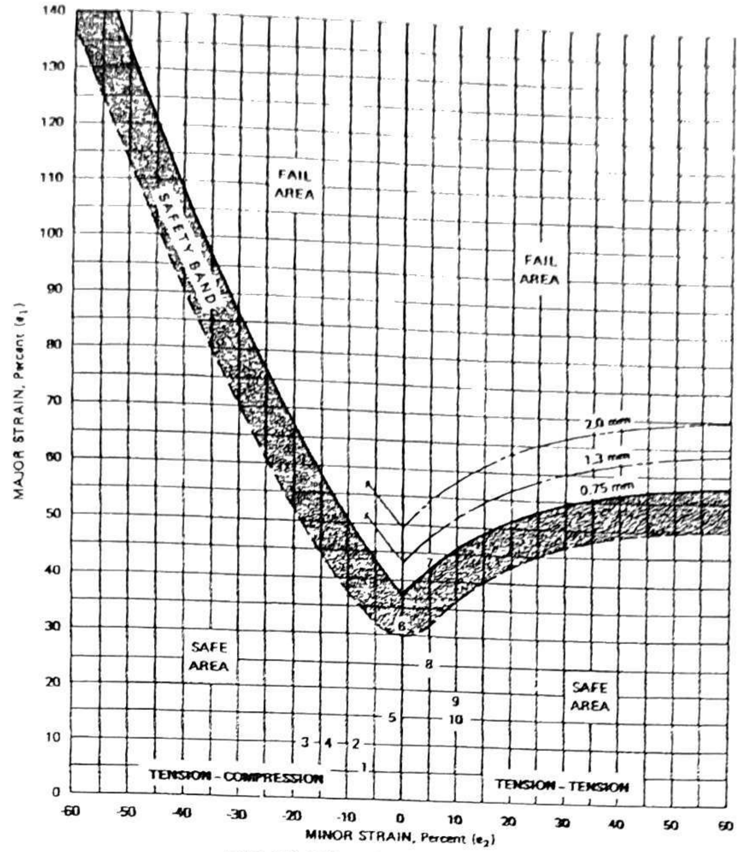


FIG. X4.1 Forming Limit Curve

the forming limit curve is lower. The magnitude of the downgrade displacement is specific to each material; therefore, current material information should be consulted to determine placement of the forming limit curve.

X4.3 Procedure

X4.3.1 Obtain a sheet sample of "known quality," the sheet quality being established by either supplier designation, consumer purchase order, or most preferred tensile data obtained from a companion sheet sample.

X4.3.2 Obtain or prepare a negative on stencil with selected circles in a uniform pattern. The circles may be 2.5 to 25.0 mm in diameter; the most convenient diameter is 5.0 mm because it is easy to read and the gage spacing is short enough to show the maximum strain in a specific location on the part.

X4.3.3 The sheet metal blanks should be cleaned to remove excess oil and dirt; however, some precoated sheets can be etched without removing the coating. The area(s) to be etched should be determined from observation of panels previously formed; generally, the area that has a split problem is selected for etching. Normally, the convex side of the radius is gridded. If sufficient time is available, the entire blank may be etched, since valuable information can be obtained about the movement of metal in stamping a part when strains can be evaluated in what may appear to be noncritical areas. Additionally, for complex shapes it may be desirable to etch both surfaces of blanks so that the strains that occur in reverse draws can be determined.

X4.3.4 The sheet metal blanks may be etched by a photographic or electrochemical method. In the former method of photosensitive solution, for example, 50 % Kodak Photo Resist (KPR) emulsion and 50 % KPR-thinner, is sprayed onto the sheet. The emulsion is dried by baking the sheet at 65°C for 15 min or by just standing it for several hours at room temperature in a dark room. The latter should be employed in materials that age and, hence, become stronger when baked at 65°C. The negative is placed on the emulsion, held intimately in contact with the sheet, and exposed to a strong ultraviolet light source for 1 to 1½ min. The sheet is developed for 30 to 45 s in KPR developer, rinsed with water, and sprayed with alcohol to set the resist. It is again rinsed with water and then sprayed with KPR black dye to reveal the etched circles.

X4.3.5 In the electrochemical method, the etch pad is saturated with an appropriate electrolyte. Various electrolytes are available from suppliers of the etching equipment. Some electrolytes are more effective than others for etching certain surfaces, such as terne plate and other metallic coated steels. A rust-inhibiting solution is preferred for steel sheets.

X4.3.6 A ground clamp for the transformer of suitable amperage (10 to 50 A is usually used) is fastened to the blank and the second lead is attached to the etch pad. Although the current may be turned on at this time, caution should be taken not to lay the pad on the sheet blank as it will arc. It is advisable to refrain from touching the metal of the etch pad and the grounded sheet blank.

X4.3.7 The stencil is placed with the plastic coating against the sheet surface in the area to be etched. Wetting the stencil with a minimum amount of electrolyte will assist in smoothing out the wrinkles and gives a more uniform etch. The etch pad is now positioned on the stencil and the current turned on, if it is not already on. Apply suitable pressure to the pad. Only the minimum time necessary to produce a clear etched pattern should be used. The etching time will vary with the amperage available from the power source and the stencil area, as well as the pad area in contact with the stencil. Rocker-type etch pads give good prints and require less amperage than flat-surfaced pads. Excessive current causes stencil damage.

X4.3.8 The etching solution activates the surface of the metal and may cause rusting unless it is inhibited. After the desired area has been etched, the blank should be wiped or rinsed, dried, and neutralized.

X4.3.9 The etched blank is now ready for forming. The lubricants and press conditions should simulate production situations. If a sequence of operations is used in forming a part, it is desirable to etch sufficient blanks so that each operation can be studied.

X4.4 Measurement of Strain After Forming

X4.4.1 After forming, the circles are generally distorted into elliptical shapes (Fig. X4.2). These ellipses have major and minor strain axes. The major strain (e_1) is always defined to be the direction in which the greatest positive strain has occurred without regard to original blank edges or the sheet rolling direction. The minor strain (e_2) is defined to be 90° to the major strain direction.

X4.4.2 There are several methods for determining the major and minor strains of the formed panel. Typical tools are a pair of dividers and a scale ruled in 0.5 mm. For sharp radii, a thin plastic scale that can follow the contour of the stamping can be used to determine the dimensions of the ellipses. (Scales are available to read the percent strain directly.)

X4.5 Evaluation of Strain Measurements

X4.5.1 The e_1 strain is always positive while the e_2 strain may be zero, positive, or negative, as indicated on the forming limit curve chart (Fig. X4.1). The maximum e_1 and associated e_2 values measured in critical areas on the formed part are plotted on the graph paper containing the forming limit curve by locating the point of intersections of the e_1, e_2 strains.

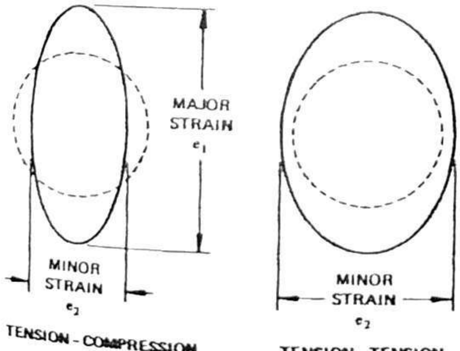


FIG. X4.2 Major and Minor Strain Axes

X4.5.2 If this point is on or below the "safety band" of the forming limit curve, the strain should not cause breakage. Points further below the curve indicate that a less ductile material of a lower grade may be applied. Points above the "safety band" show that fabrication has induced strains that could result in breakage. Therefore, in evaluation on stampings exhibiting these strains, efforts should be made to provide an e_1, e_2 strain combination that would lie on or below the "safety band" of the forming limit curve. A different e_1, e_2 strain combination can be obtained through changes of one or more of the forming variables such as die conditions, lubricants, blank size, thickness, or material grade. It should be noted at this time that these conclusions are derived from a reference base being the steel "quality" used to fabricate the grid stamping.

X4.5.3 When attempting to change the relationship of e_1 and e_2 strains, it should be noted that on the forming limit curve the most severe condition for a given e_1 strain is at 0 % e_2 strain. This means the metal works best when it is allowed to deform in two dimensions, e_1 and e_2, rather than being restricted in one dimension. A change in e_2 to decrease the severity can be made by changing one of the previously mentioned forming variables of the die design, for example, improving lubrication on the tension-tension side will increase e_2 and decrease the severity.

X4.5.4 In addition to the forming limit curve, the e_1e_2 strain measurements may be used to evaluate the material requirements on the basis of strain gradients, as illustrated in Fig. X4.3, or by plotting contours of equivalent strain levels on the surface of the formed part. Even when the level of strain is relatively low, parts in which the e_1 strain is changing rapidly either in magnitude or direction over a short span on the surface may require more ductile grades of sheet metal, change in lubrication, or change in part design.

X4.6 Example of Major and Minor Strain Distribution

X4.6.1 A formed panel (Fig. X4.4) with a cross section as shown in Fig. X4.3 is used to illustrate major and minor strain

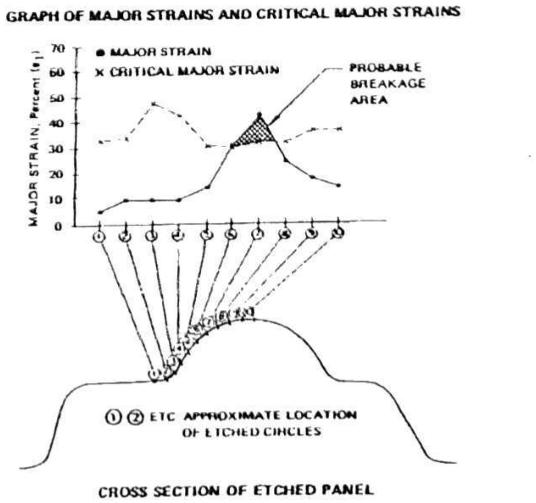


FIG. X4.3 Graph of Major Strains and Critical Major Strains and Cross Section of Etched Panel

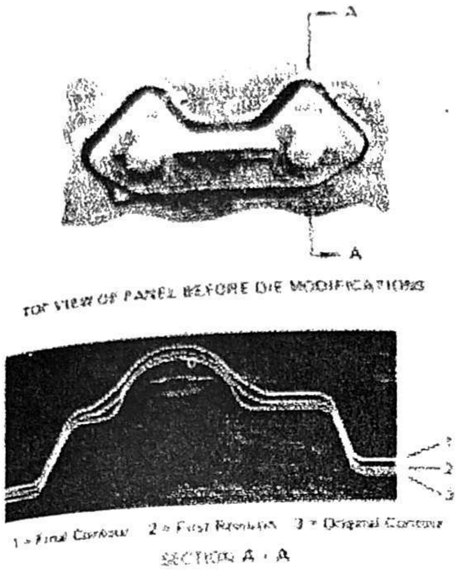


FIG. X4.4 Formed Panel and Cross Section

combinations. A plot of the major strain distribution should be made by finding the ellipse with the largest major strain (circle 7) and measuring both the major and minor strains in the row of ellipses running in the direction of the major strain. The solid dots (Fig. X4.3) are the measured major strains for each ellipse. The Xs are the critical major strains as determined from the forming limit curve at the corresponding minor strain (intersection of the measured minor strain and the severity curve).

X4.6.2 Usually a single row of ellipses will suffice to determine the most severe strain distribution. The resulting strain distribution plot (Fig. X4.3) illustrates both severity of the strain compared to the critical strain limits and the concentration of strain in the stamping. Steep strain gradients should be avoided because they are inherent to fracture sites.

X4.7 Example for Reducing Splitting Tendency

X4.7.1 In an area such as that represented in Fig. X4.3, the splitting tendency can be reduced as follows:

X4.7.1.1 If the radius of the part in the region of circle 1 is increased, some strain can be induced to take place in this area which will allow the major strain in circle 7 to be reduced sufficiently to bring the strain combination below the critical limit. This course of action requires no binding nor reshaping of the punch, only grinding in the radius.

X4.7.1.2 The total average major strain required to make this formation is only 17.5 %; yet in a 5.0-mm circle the strain is as high as 40 %. The strain distribution curve puts forth graphically the need to distribute the strain over the length of the time by some means as described above.

X4.7.1.3 Change in lubrication can also improve the strain distribution of a stamping. If the strain over the punch is critical, the amount of stretch (strain) required to make the shape can be reduced by allowing metal to flow in over the punch by decreasing the friction through the use of a more effective lubricant in the hold-down era.

X4.7.1.4 If the part is critical, a change in material may help. That is, a material having a better uniform elongation will distribute the strain more uniformly or a material having a higher "r" value will make it possible to "draw" in more metal from the hold-down area so that less stretch is necessary to form the part.

X4.8 Scribed Square Method

X4.8.1 The basic technique is to draw a panel from a blank that has been scribed both longitudinally and transversely with a series of parallel lines spaced at 25.0-mm intervals. The lines on the panel are measured after drawing and the stretch or draw calculated as the percent increase in area of a 25.0-mm square. This is a fairly simple procedure for panels having generous radii and fairly even stretch or draw. Many major panels fall in this category, and in these instances it is quite easy to pick out the square area exhibiting the greatest increase.

X4.8.2 If the square or line to be measured is no longer a flat surface, place a narrow strip of masking (or other suitable tape) on the formed surface and mark the points which are to be measured. Remove the tape, place on a plane surface, and determine the distance between the points with a steel scale.

X4.8.3 There will be cases of minor increase in area with major elongation in the one direction. In these instances, the percent elongation should be recorded.

X4.9 Thickness Method

X4.9.1 There are instances when the maximum stretch is continued to an area smaller than 645 mm^2 or the shape of the square has been distorted irregularly, making measurements difficult and calculation inaccurate. When either of these conditions exists, an electronic thickness gage may be used at the area in question or this area may be sectioned and the decrease in metal thickness measured with a ball-point micrometer. The increase in unit area can be calculated by dividing the original thickness by the final thickness.

X4.9.2 *Example*

Assuming the blank thickness to be 0.80 mm and the final thickness to be 0.60 mm, the increase in unit area would be a $[(0.80 - 0.60)/0.80] \times 100 = 25$ % increase.

X5. ALTERNATIVE METHODS FOR EXPRESSING FLATNESS

X5.1 Introduction and Definitions

X5.1.1 In addition to the conventional expression of flatness, the "maximum deviation from a horizontal flat surface", at least two other flatness parameters have been developed and are in use for characterizing sheet with longitudinal waves or buckles. These are *steepness index* and *flatness index* (or "I-unit"), that are illustrated using the example in Fig. X5.1.

X5.1.2 *Steepness Index*—Fig. X5.1(*a*) shows a representation of a sheet sample exhibiting edge waves of height, *H*, and interval, *L*. The steepness index value for this sample is defined as:

$$\text{steepness index} = H/L$$

Often, the steepness value is expressed as a percentage:

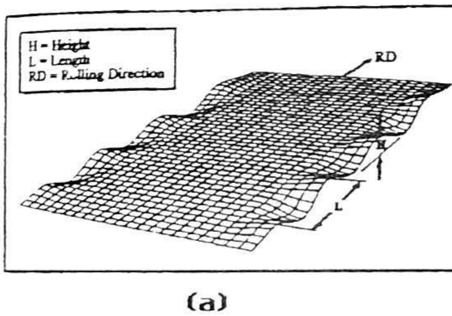
$$\%\ \text{steepness} = S = (H/L) \times 100$$

X5.1.3 *I-Units*—Making a series of lengthwise cuts to the sample in Fig. X5.1(*a*) relaxes elastic stresses present in the sheet and results in narrow strips of differing lengths, as shown in Fig. X5.1(*b*). Using the length of one of these strips as a reference (L_{ref}), the I-unit value (*I*) for an individual strip is defined as:

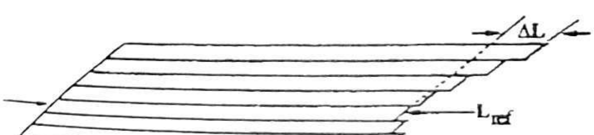
$$I = (\Delta L/L_{ref}) \times 10^5$$

where:

ΔL is the difference between the length of a given strip and the reference strip.



(a)



(b)

FIG. X5.1 Representation of Sheet Sample With Edge Waves (*a*) and Strips of Differing Length That Result from Making Longitudinal Cuts Along the Sample (*b*)

X5.1.4 For the special case of waves/buckles that are perfectly sinusoidal in character, the following relationship applies:

$$I = \left[\left(\frac{\pi}{2}\right)\left(\frac{H}{L}\right)\right]^2 \times 10^5$$

or:

$$I = 24.7S^2$$

Table X5.1 provides I-unit values based on the sinusoidal approximation for wave heights up to ½-in. (increments of 1⁄32 in.) and intervals between 10 and 40 in. (increments of 1 in.). Mathematical relationships between the three representations of flatness described here are given in Table X5.2; these relationships can be used to convert between I-unit, % steepness, and wave height values (see examples in Table X5.2).

X5.2 Flatness Evaluation Example and Determination of I-Unit or % Steepness Value

X5.2.1 While the strip is on an inspection table, find the locations on the strip that are not lying flat on the table. If no flatness deviation can be found, that portion of the coil (head/middle/tail) can be described as flat (that is, zero I-unit or zero % steepness).

X5.2.2 If the coil is not totally flat, the height of the deviation must be determined and recorded. If the coil has edge waves, a step gauge (incremented in intervals of 1⁄16 or 1⁄32 in.) can be inserted under a wave to determine the height. If the coil exhibits flatness deviation in the center of the strip, a lightweight straight edge can be placed on the highest portion of the buckle and on the highest portion of the next repeating buckle. The height can then be determined by inserting a step gauge between the straight edge and the strip.

X5.2.3 Along with the height, the wave period or wave interval must also be determined. The wave interval can be obtained by using a standard tape measure or straight edge to measure the distance between the highest point of one flatness deviation to the highest point of the next repeating flatness deviation.

X5.2.4 After determining height and wave interval, either the I-unit or % steepness value can be obtained. To determine the I-unit flatness, locate the appropriate height and wave interval in Table X5.1 and read the I-unit value at the intersection of the two measurements. To determine % steepness, divide the height by the wave interval and multiply the result by 100.

TABLE X5.1 I-Unit Conversion Chart

Wave Height (in.)	Wavelength (in.) 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1/32	2	2	2	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1/16	10	8	7	6	5	4	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3/32	22	18	15	13	11	10	8	8	7	6	5	5	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2	1	1
1/8	39	32	27	23	20	17	15	13	12	11	10	9	8	7	7	6	6	5	5	5	4	4	4	4	3	3	3	3	3	3	2
5/32	60	50	42	36	31	27	24	21	19	17	15	14	12	11	10	10	9	8	8	7	7	6	6	6	5	5	5	4	4	4	4
3/16	87	72	60	51	44	39	34	30	27	24	22	20	18	16	15	14	13	12	11	10	10	9	8	8	8	7	7	6	6	6	5
7/32	118	98	82	70	60	53	46	41	38	33	30	27	24	22	21	19	17	16	15	14	13	12	12	11	10	10	9	9	8	8	7
1/4	154	128	107	91	79	69	60	53	48	43	39	35	32	29	27	25	23	21	20	18	17	16	15	14	13	13	12	11	11	10	10
9/32	195	161	136	116	100	87	76	68	60	54	49	44	40	37	34	31	29	27	25	23	22	20	19	18	17	16	15	14	14	13	12
5/16	241	199	168	143	123	107	94	83	74	67	60	55	50	46	42	39	36	33	31	29	27	25	24	22	21	20	19	18	17	16	15
11/32	292	241	203	173	149	130	114	101	90	81	73	66	60	55	51	47	43	40	37	35	32	30	29	27	25	24	23	21	20	19	18
3/8	347	287	241	206	177	154	136	120	107	96	87	79	72	66	60	56	51	48	44	41	39	36	34	32	30	28	27	25	24	23	22
13/32	408	337	283	241	208	181	159	141	126	113	102	92	84	77	71	65	60	56	52	48	45	42	40	37	35	33	31	30	28	27	25
7/16	473	391	328	280	241	210	185	164	146	131	118	107	98	89	82	76	70	65	60	56	53	49	46	43	41	39	38	35	33	31	30
15/32	543	449	377	321	277	241	212	188	168	150	136	123	112	103	94	87	80	74	69	65	60	56	53	50	47	44	42	40	38	36	34
1/2	618	510	429	365	315	274	241	214	191	171	154	140	128	117	107	99	91	85	79	73	69	64	60	57	53	50	48	45	43	41	39

Wave Height (mm)	Wavelength (mm) 250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625	650	675	700	725	750	775	800	825	850	875	900	925	950	975	1000
0.5	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0	4	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1.5	9	7	6	5	5	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2.0	16	13	11	9	8	7	6	5	5	4	4	4	3	3	3	3	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1
2.5	25	20	17	15	13	11	10	9	8	7	6	6	5	5	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2
3.0	36	29	25	21	18	16	14	12	11	10	9	8	7	7	6	6	5	5	5	4	4	4	3	3	3	3	3	3	2	2	2
3.5	48	40	34	29	25	22	19	17	15	13	12	11	10	9	8	8	7	7	6	6	5	5	5	4	4	4	4	4	3	3	3
4.0	63	52	44	37	32	28	25	22	20	18	16	14	13	12	11	10	9	9	8	8	7	7	6	6	5	5	5	5	4	4	4
4.5	80	66	56	47	41	36	31	28	25	22	20	18	17	15	14	13	12	11	10	10	9	8	8	7	7	7	6	6	6	5	5
5.0	99	82	69	58	50	44	39	34	30	27	25	22	20	19	17	16	15	14	13	12	11	10	10	9	9	8	8	7	7	6	6
5.5	120	99	83	71	61	53	47	41	37	33	30	27	25	23	21	19	18	16	15	14	13	12	12	11	10	10	9	9	8	8	7
6.0	142	118	99	84	73	63	56	49	44	39	36	32	29	27	25	23	21	20	18	17	16	15	14	13	12	12	11	10	10	9	9
6.5	167	138	116	99	85	74	65	58	52	46	42	38	34	32	29	27	25	23	21	20	19	17	16	15	14	14	13	12	12	11	10
7.0	194	160	134	115	99	86	76	67	60	54	48	44	40	37	34	31	29	27	25	23	22	20	19	18	17	16	15	14	13	13	12
7.5	222	184	154	132	113	99	87	77	69	62	56	50	46	42	39	36	33	30	28	26	25	23	22	20	19	18	17	16	15	15	14
8.0	253	209	176	150	129	112	99	88	78	70	63	57	52	48	44	40	37	35	32	30	28	26	25	23	22	21	20	18	18	17	16
8.5	286	236	198	169	146	127	112	99	88	79	71	65	59	54	50	46	42	39	36	34	32	30	28	26	25	23	22	21	20	19	18
9.0	320	265	222	189	163	142	125	111	99	89	80	73	66	61	56	51	47	44	41	38	36	33	31	29	28	26	25	23	22	21	20
9.5	357	295	248	211	182	159	139	123	110	99	89	81	74	67	62	57	53	49	45	42	40	37	35	33	31	29	28	26	25	23	22
10.0	395	327	274	234	202	176	154	137	122	109	99	90	82	75	69	63	58	54	50	47	44	41	39	36	34	32	30	29	27	26	25

TABLE X5.2 Flatness Conversion Factors[A]

NOTE 1—"L" is the wave interval as defined in Fig. X5.1 (*a*)

	I Unit	Height	% Steepness
I Unit (I)	1	$\frac{2L}{\pi}\sqrt{I\,10^{-5}}$	$\frac{2}{\pi}\sqrt{I\,10^{-5}}$
Height (H) (peak to peak)	$\left(\frac{H\pi}{2L}\right)^2 10^5$	1	$\frac{(100\,H)}{L}$
% Steepness (S)	$2.5(\pi S)^2$	$\frac{(LS)}{100}$	1

[A] Examples—(*1*) Assume % steepness is given as 1.5 and the corresponding I-unit value is desired. From Table X5.2, $I = 2.5(\pi S)^2 = 2.5[(3.14)(1.5)]^2 = 55.5$. (*2*) Assume an I-unit value of 25 is given and the corresponding % steepness is desired. From Table X5.2, $S = 2/\pi(I \times 10^{-1})^{1/2} = 2/3.14\,(25 \times 10^{-1})^{1/2} = 1.0$.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 568/A 568M – 02) that may impact the use of this standard.

(1) A revision was made to Section 3.1.5.
(2) The following Tables were revised: Tables 4, 5, 6, 7, 15, and 16.