Engineering Design ENGR 13x2

Engineering Tools II

Agenda

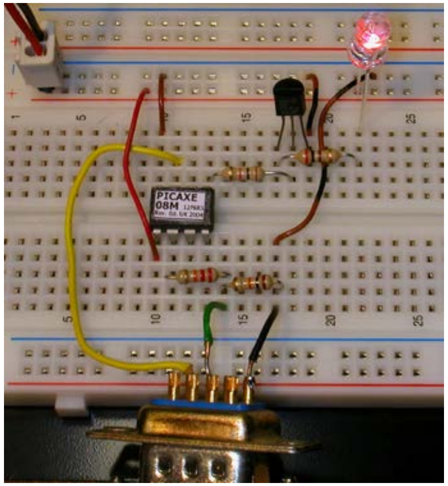
- Prototyping
- Computer Analysis and Simulation
- Solid Modeling and CAD
- Engineering Drawings
- Information Sources

Prototyping

- Mock-up of the finished product that includes important features but omits non-essential elements:
  - Making it “pretty”
  - Features not critical to its operation
- Make it cheap(er), with materials that are easy to machine, etc.
- Changes can be readily made
- Allows for testing and analysis

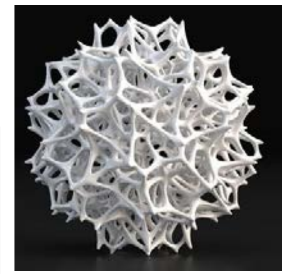
Prototyping

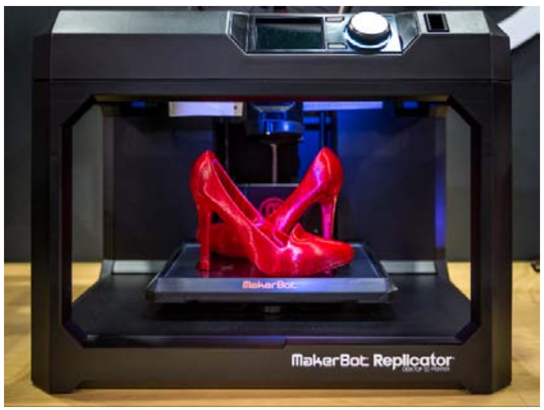
- Used in nearly every field of engineering
  - Mechanical prototypes
  - Breadboarding
  - Scale modeling
  - Other examples
    - Software code
    - Process simulation



Rapid prototyping

- 3d Printing





- http://www.youtube.com/watch?v=NueRhgISweE&feature=relmfu

Reverse engineering

- Dissecting someone else’s product to learn how it works.
- Practiced by companies worldwide.
- Don’t use it to steal someone else’s design!

Computer Analysis & Simulation

- Excel
  - Everybody has it
  - Limited but useful
- Mathcad
  - Graphical Equations
- Matlab
  - Built for matrix math
  - Large library of built in functions
- LabView
  - Graphical programming
  - Used often to record experimental data

Calculate the exit velocity for a 100 meter long pipe.

$H := 20 \quad g := 9.8 \quad d := 0.5 \quad v := .0000010 \quad L := 100$ (SI units)

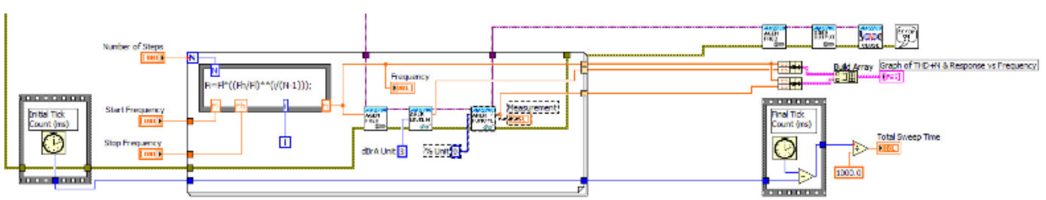
$ks := .000046$

Extended Bernoulli Equation
with f by Haaland Correlation

$$s(x) := \frac{x^2}{2\cdot g}\cdot\left[4\cdot\frac{L}{d}\cdot\left[3.4735 - 1.5635\cdot\ln\left[\left(2\cdot\frac{ks}{d}\right)^{1.11} + 63.635\cdot\frac{v}{d\cdot x}\right]\right]^{-2} + 1\right] - H$$

```
function ye = kalmanf(A,B,C,Q,R,u,t,yv) %#eml
P = B*Q*B';                          % Initial error covariance
x = zeros(size(B));                  % State initial condition
ye = zeros(length(t),1);
errcov = zeros(length(t),1);
for i=1:length(t)
  % Measurement update
  Mn = P*C'/(C*P*C'+R);
  x = x + Mn*(yv(i)-C*x);          % x[n|n]
  P = (eye(size(A))-Mn*C)*P;       % P[n|n]
  % Compute output
  ye(i) = C*x;
  errcov(i) = C*P*C';
  % Time update
  x = A*x + B*u(i);                 % x[n+1|n]
  P = A*P*A' + B*Q*B';              % P[n+1|n]
end
```

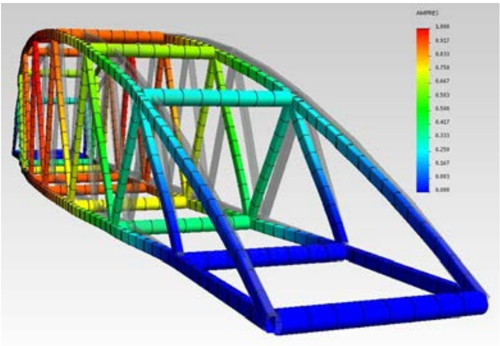
Garbage In – Garbage Out!

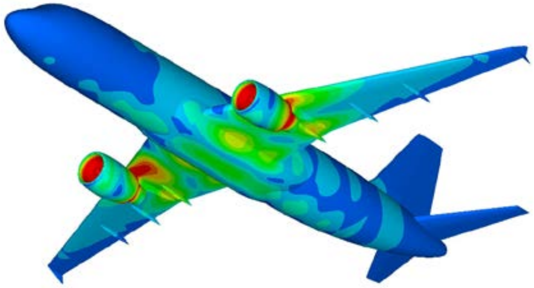


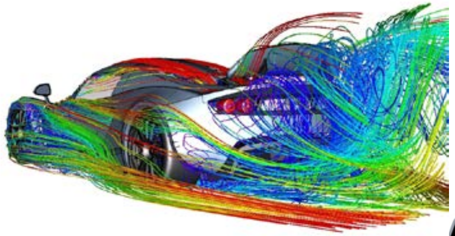
Computer Analysis & Simulation

- Modeling system behavior
  - Process Flow
  - Fluid Flow
  - Chemical Processes
  - Construction
  - FEA and CFD
    - Finite Element Analysis (FEA)
    - Computational Fluid Dynamics (CFD)

https://www.youtube.com/watch?v=bTp1DRfULII





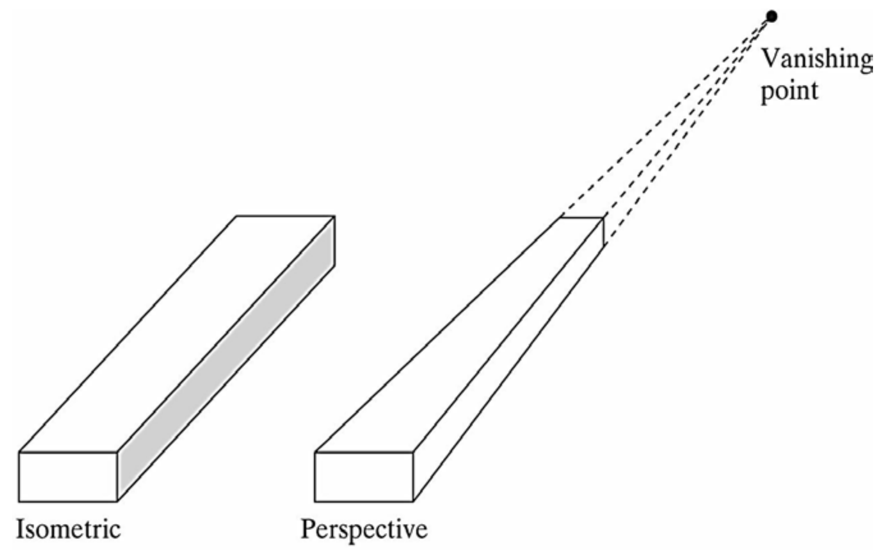


Solid modeling and CAD

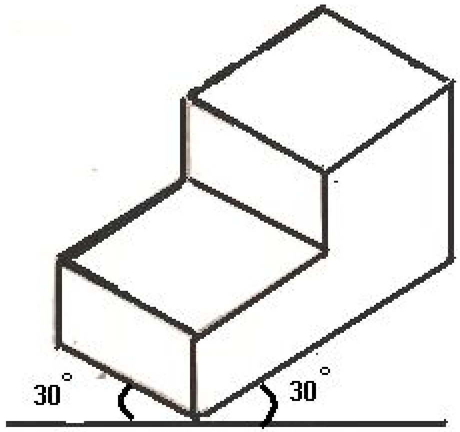
- Solid models
  - Complete mathematical description, not just visual.
  - Useful for:
    - Analysis and Animations
    - Rendering for product literature
    - Computer-aided manufacturing
    - Rapid prototyping
- Formal drawings are the link between engineers, technicians, fabricators, customers, etc.

Solid modeling and CAD

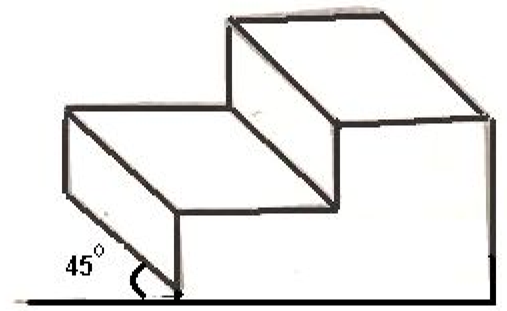
- Drawing views/projections
  - Isometric view
    - Parallel sides drawn as parallel lines on page
    - Undistorted depth
  - Perspective view
    - Parallel sides drawn to a “vanishing point”
    - Tricks the eye into perceiving a third dimension or depth



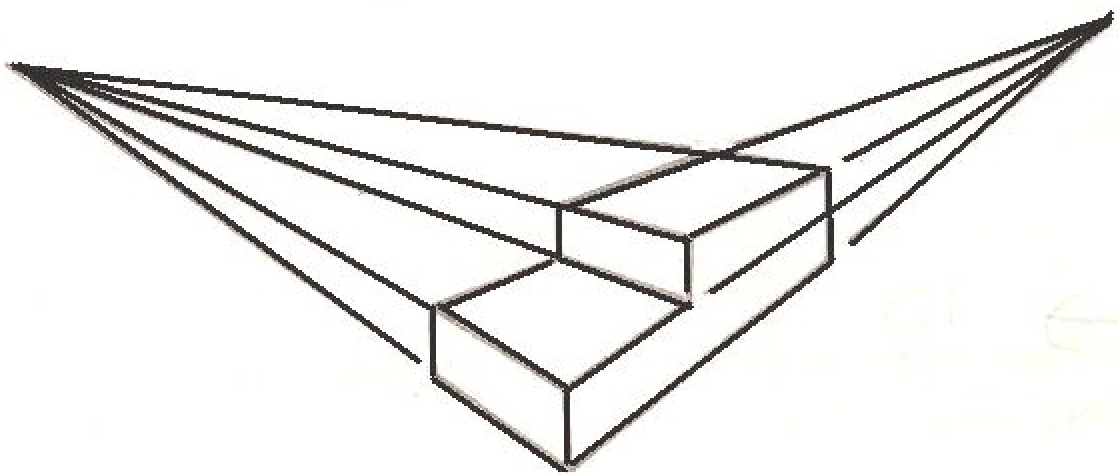
Solid modeling and CAD



Isometric



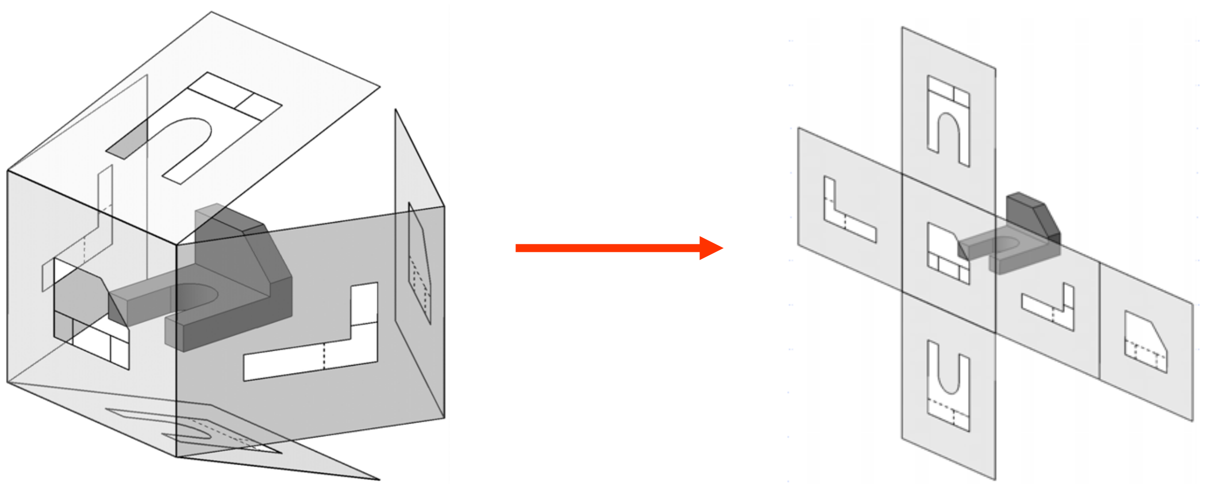
Oblique



Perspective

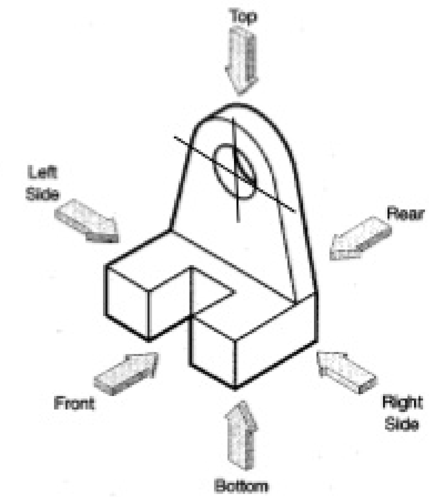
Solid modeling and CAD

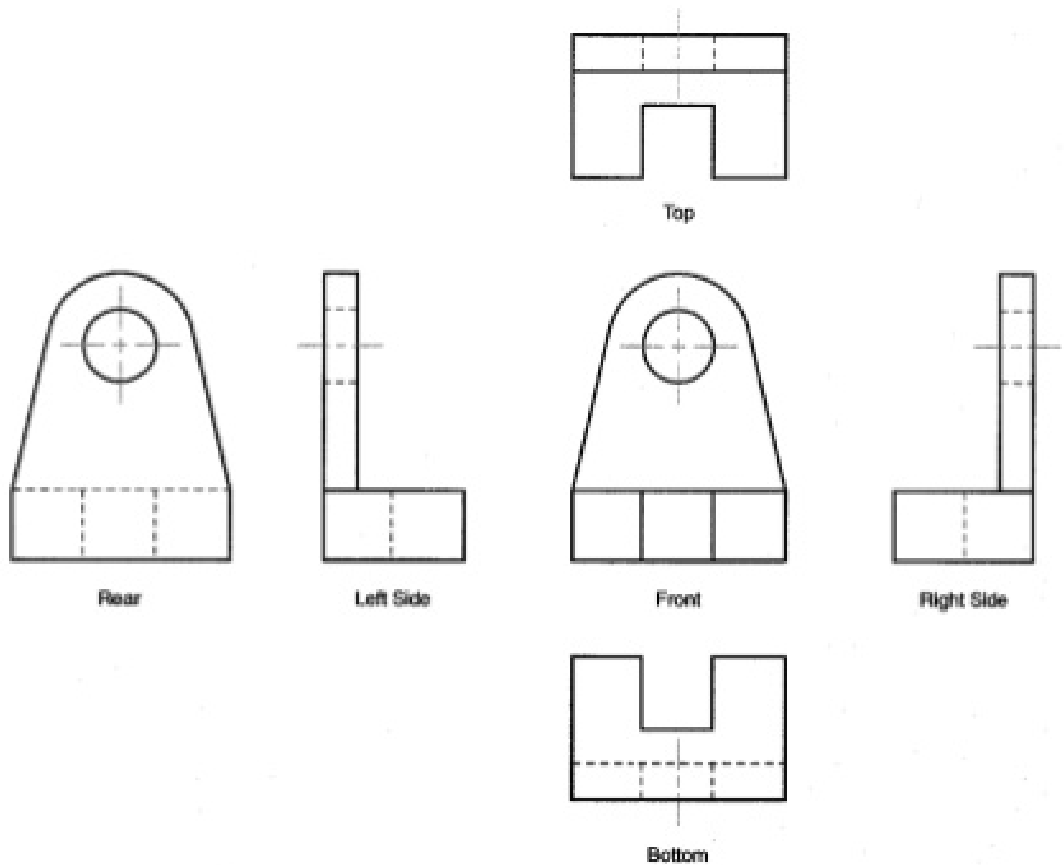
- Orthographic Projections
  - 2D representation of 3D object
  - Standard Format (front view, top view, right side view)
  - Other views used as necessary



Solid modeling and CAD

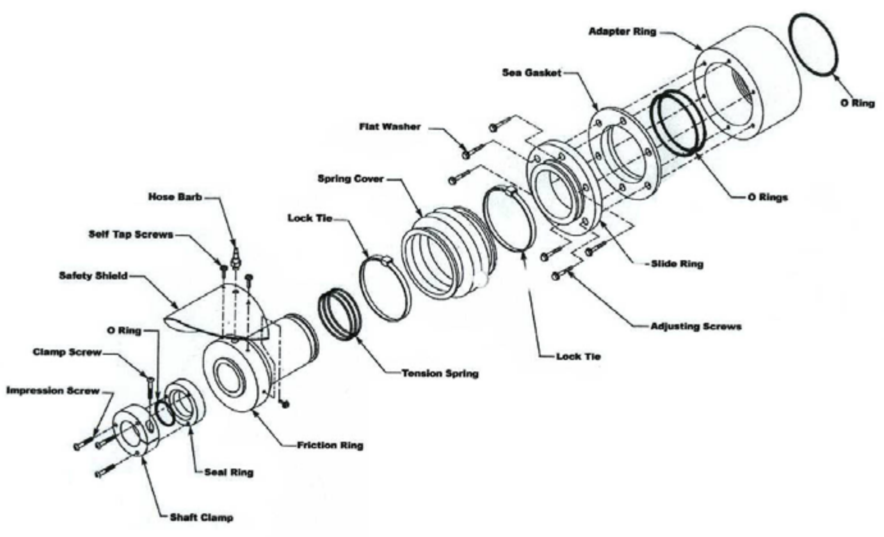
- Proper view alignment is required!

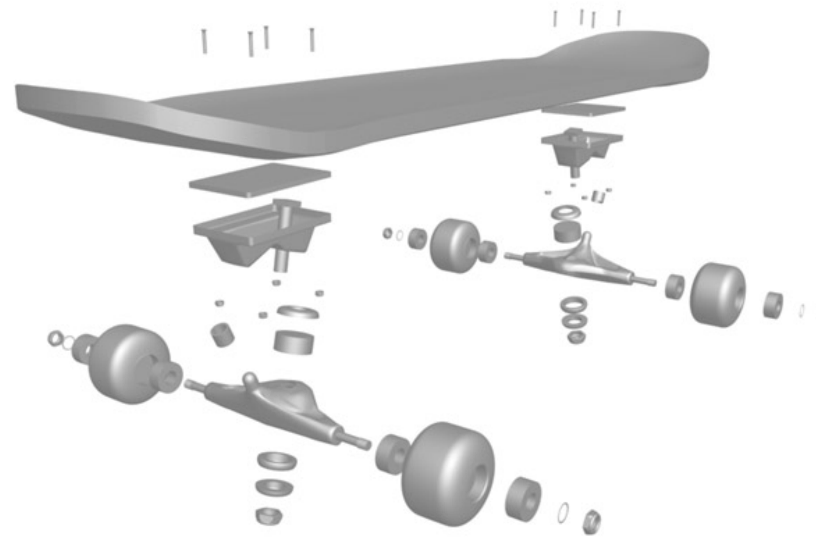




Solid modeling and CAD

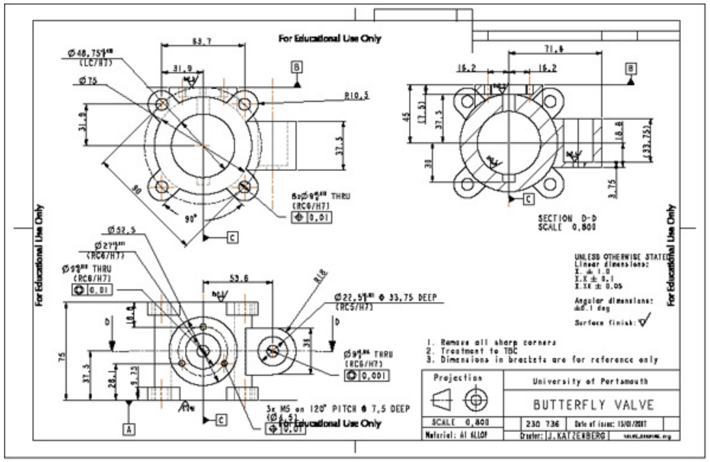
- Exploded View
  - Describes how multiple parts are assembled
  - Dotted lines may convey paths for connection
  - Can be used for drawings and product literature

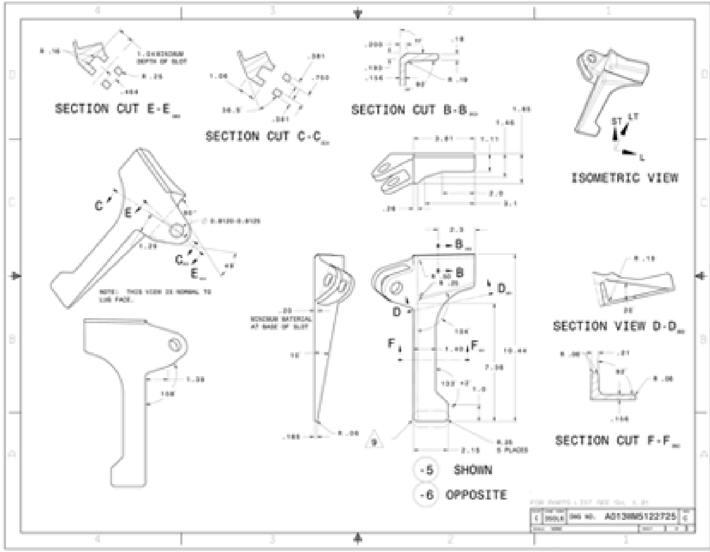




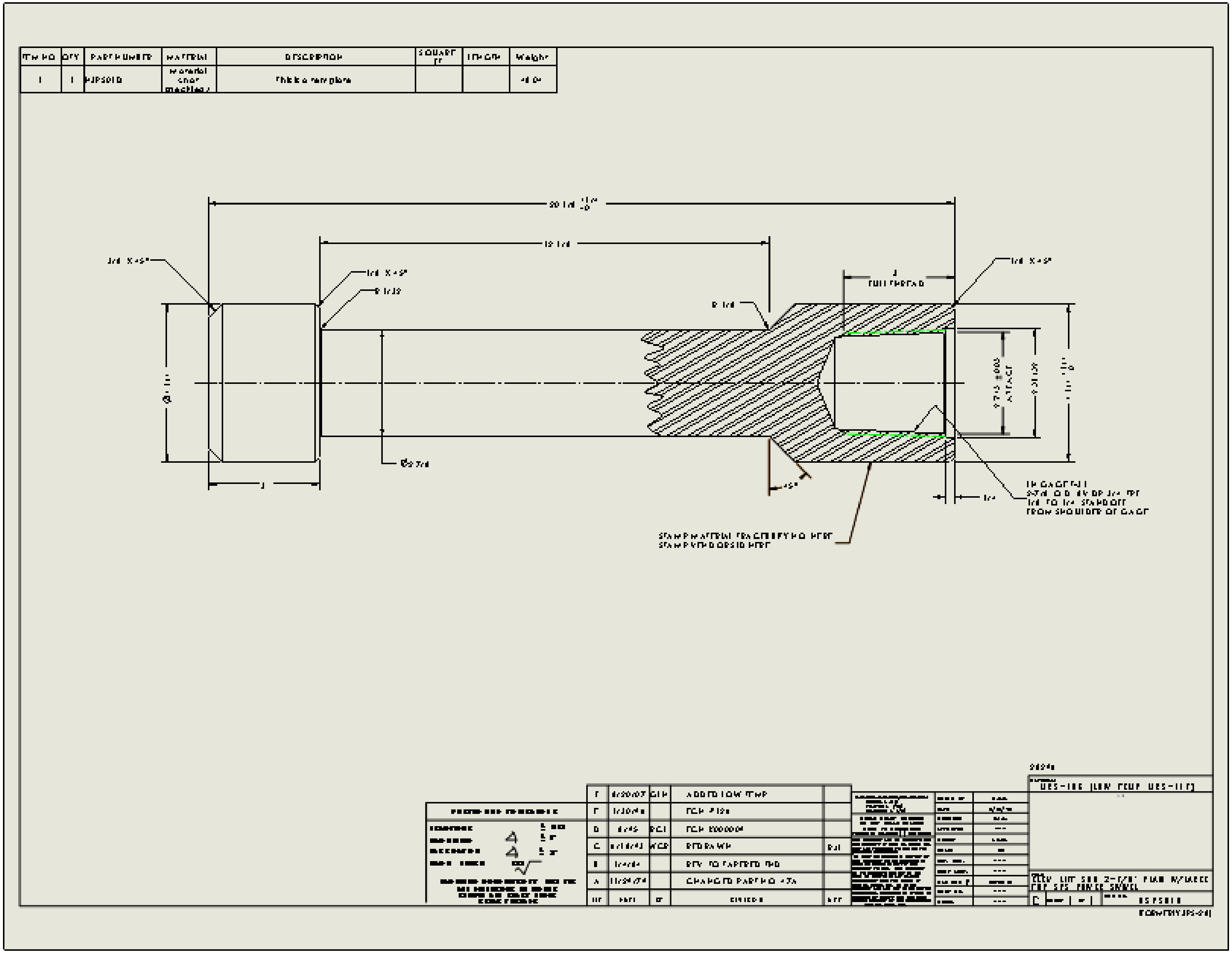
Engineering Drawings

- Final released drawings should:
  - Capture all required information to define the design and permit its analysis, manufacturing, and verification
  - Include processes, material, and parts data, for example:
    - AMS 2403 Nickel Plating (process, cleaning, adhesion)
    - ASTM F837M Stainless Steel Socket Head Cap Screws, Metric (dimensions, finish, strength statistics)
    - Metallic Materials Properties Development and Standardization (MMPDS) (alloys, strength, stress-strain)

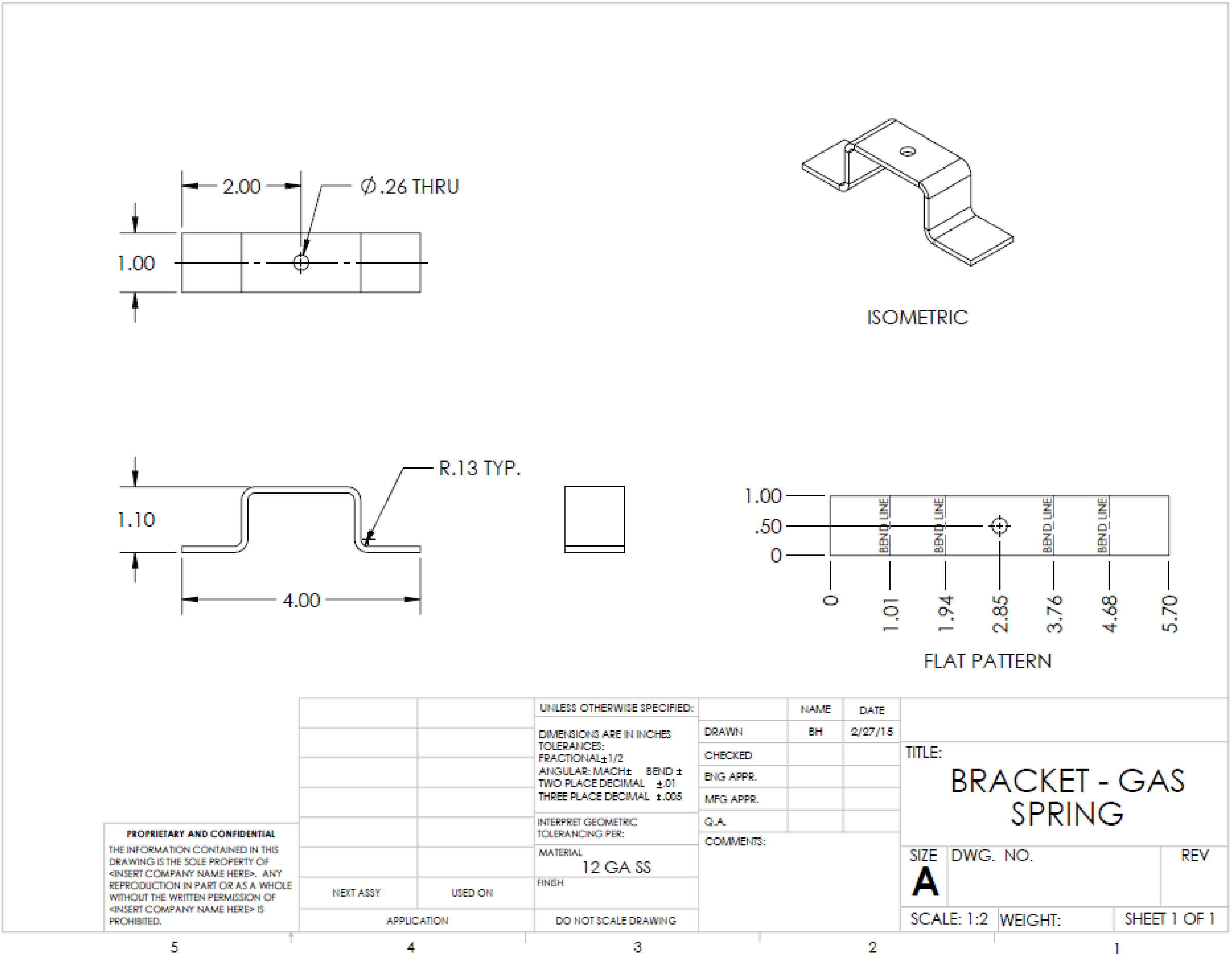




Machined Part Drawing

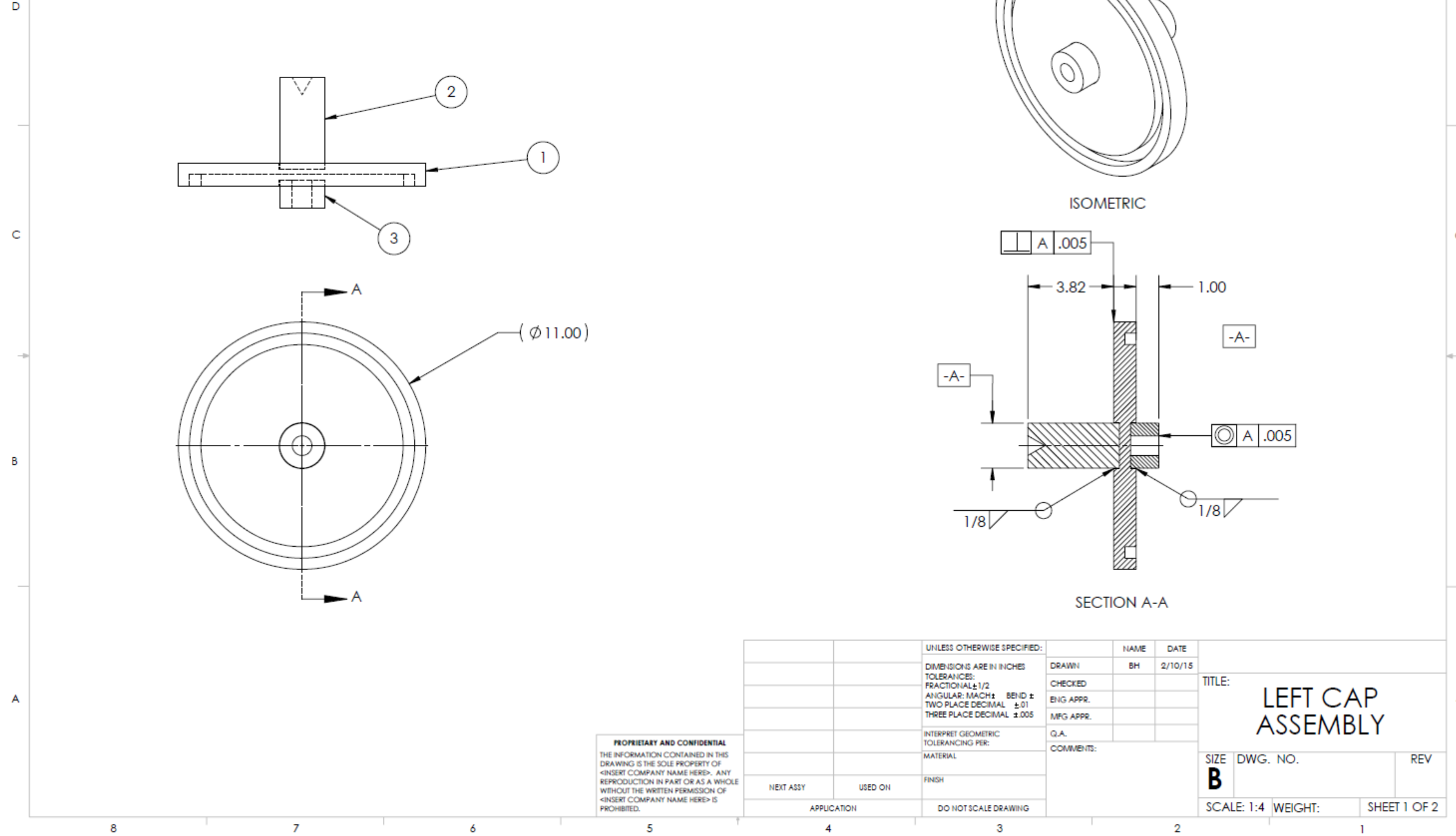


Sheet Metal Part Drawing

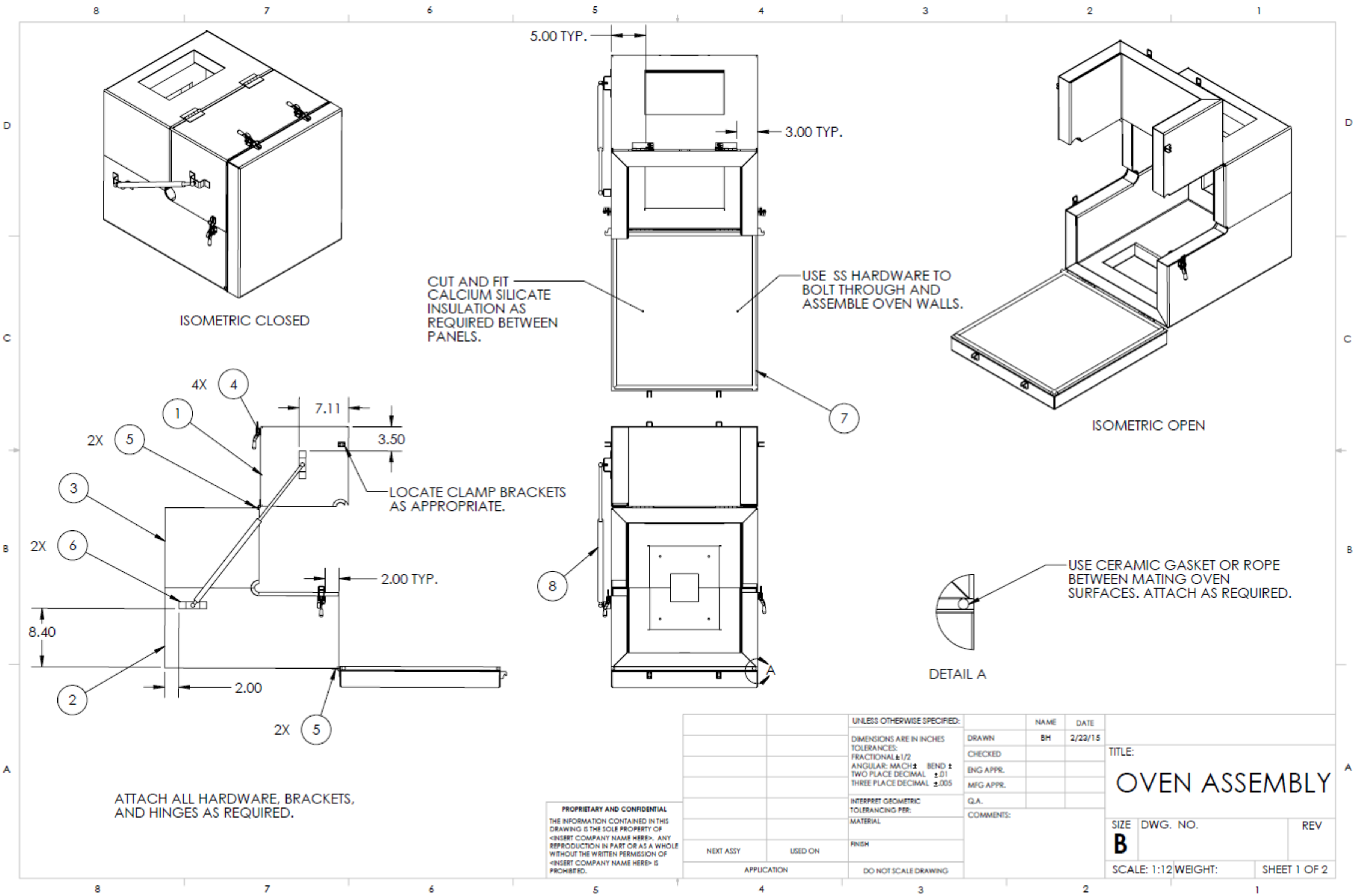


Welded Assembly Drawing

ITEM NO.	QTY.	DESCRIPTION	MATERIALS
1	1	CAP END	A-36 STEEL OR 1018 STEEL
2	1	OUTSIDE INSERT	A-36 STEEL OR 1018 STEEL
3	1	A-36 STEEL OR 1018 STEEL	A-36 STEEL OR 1018 STEEL



Assembly Drawing – Page 1



Assembly Drawing – Page 2

ITEM NO.	Default/QTY.	PART NUMBER	DESCRIPTION
1	1	TOP DOOR ASSEMBLY	
2	1	OVEN BOTTOM ASSEMBLY	
3	1	OVEN TOP COVER ASSEMBLY	
4	4	5071A51	CLAMP: MCMASTER CARR
5	4	16175A19	HINGE: MCMASTER CARR
6	2	GAS SPRING BRACKET	12 GA SS
7	1	FRONT DOOR ASSEMBLY	
8	1	4138T61	GAS SPRING: MCMASTER CARR
9		9391K63	2" CALCIUM CILICATE INSULATION: MCMASTER CARR

NEXT ASSY | USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/2
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	BH	2/23/15
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

OVEN ASSEMBLY

SIZE B | DWG. NO. | REV

SCALE: 1:16 | WEIGHT: | SHEET 2 OF 2

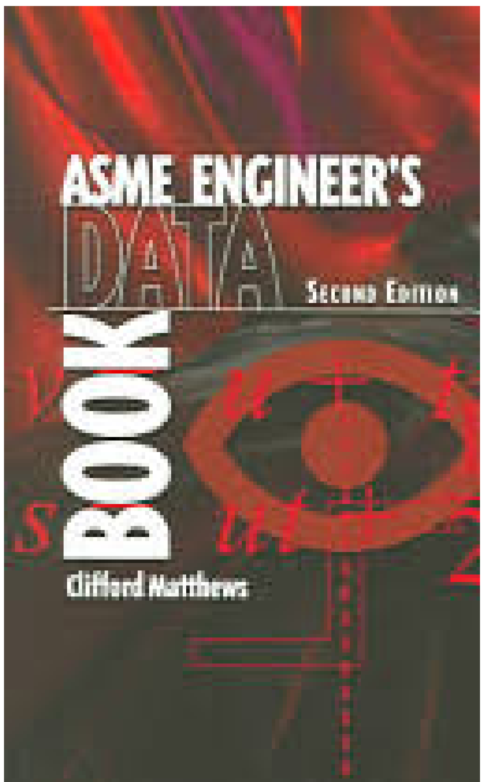
Information Sources

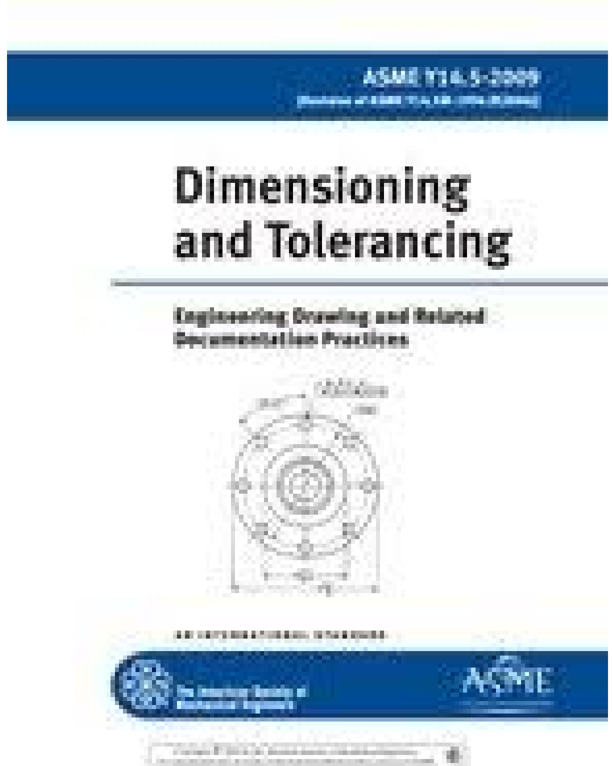
"A month in the laboratory can often save an hour in the library" – Frank Westheimer, *chemist and Harvard Professor*

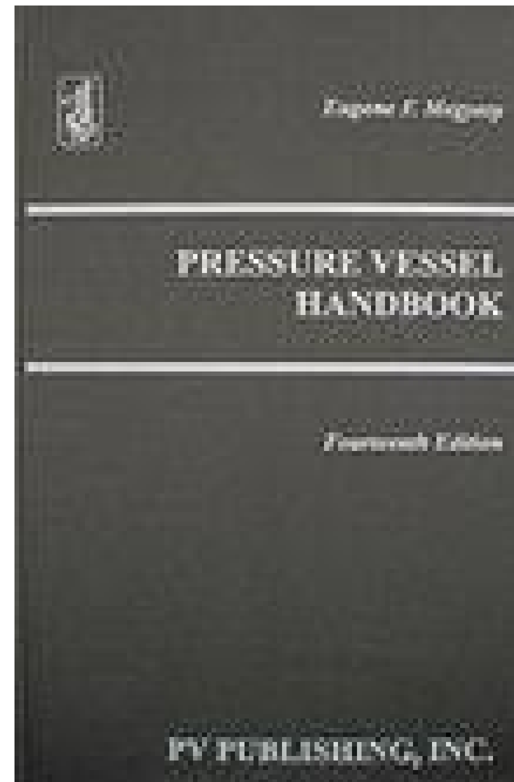
- Information is everywhere – knowledge and wisdom are scarce!
- Information Sources
  - Books (textbooks, technical books, etc.)
  - Handbooks & Specifications
  - Journals
  - Industry Publications
  - Vendors & Suppliers
  - Colleagues

Handbooks

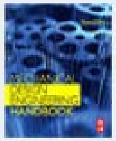
- Reference documents for established data and processes
- Often from professional societies and government organizations
  - Examples of ASME handbooks:







Other Examples:



Full text online via Library

BOOK TITLES

Mechanical Design Engineering Handbook

Save to My Knovel

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Citation

DESCRIPTION

This book is a straight-talking and forward-thinking reference covering the design, specification, selection, use and integration of machine elements fundamental to a wide range of engineering applications. Develop or refresh your mechanical design skills in the areas of bearings, shafts, gears, seals, belts and chains, clutches and brakes, springs, fasteners, pneumatics and hydraulics, amongst other core mechanical elements, and dip in for principles, data and calculations as needed to inform and evaluate your on-the-job decisions.

AUTHOR/EDITOR

Childs, Peter R.N.

PUBLISHER

Elsevier

COPYRIGHT DATE

2014

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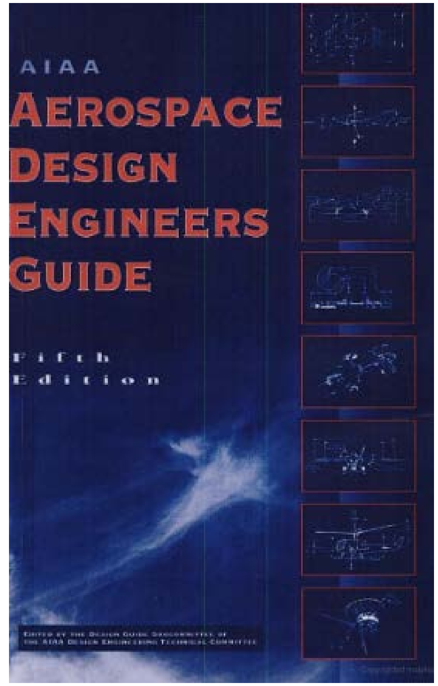
SECTION



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NOT MEASUREMENT SENSITIVE

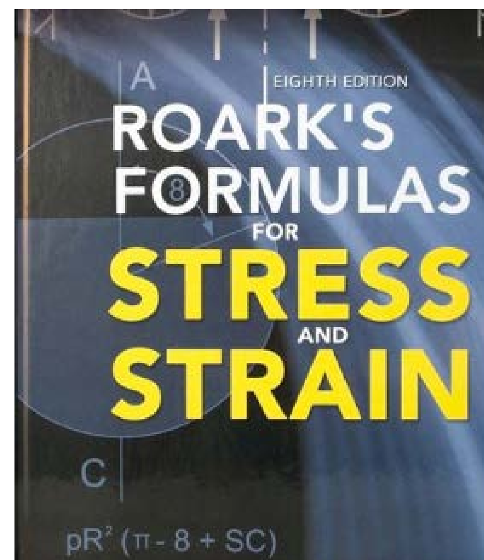
National Aeronautics and Space Administration

NASA-HDBK-5010
MAY 24, 2005

FRACTURE CONTROL IMPLEMENTATION HANDBOOK FOR PAYLOADS, EXPERIMENTS, AND SIMILAR HARDWARE

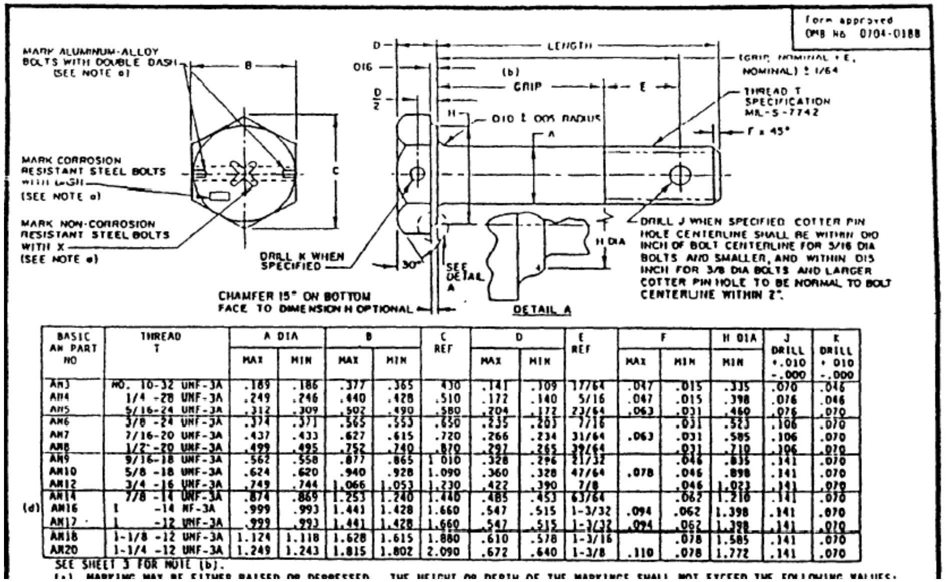
NASA TECHNICAL HANDBOOK

APPROVED FOR PUBLIC RELEASE – DISTRIBUTION IS UNLIMITED



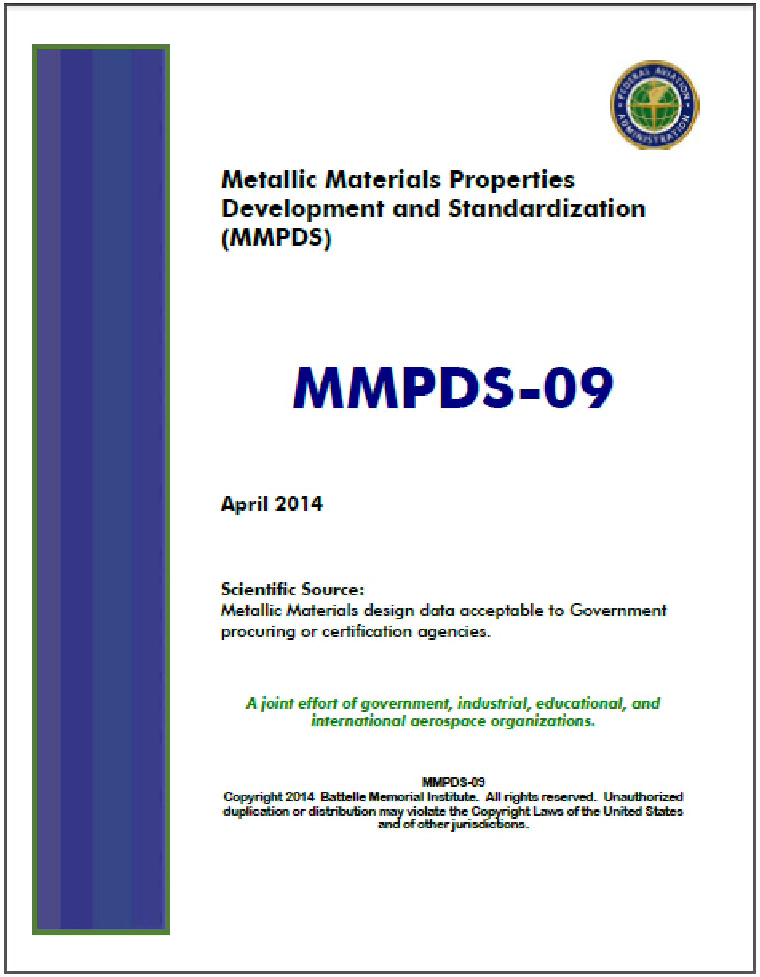
Specifications

- Detailed data on material properties and processes



	BASIC AN PART NO	THREAD T	A DIA		B		C REF	D		E REF	F		H DIA	J DRILL +.010 -.000	K DRILL +.010 -.000
			MAX	MIN	MAX	MIN		MAX	MIN		MAX	MIN	MIN		
	AN3	NO. 10-32 UNF-3A	.189	.186	.377	.365	.430	.141	.109	17/64	.047	.015	.335	.070	.046
	AN4	1/4 -28 UNF-3A	.249	.246	.440	.428	.510	.172	.140	5/16	.047	.015	.398	.076	.046
	AN5	5/16-24 UNF-3A	.312	.309	.502	.490	.580	.204	.172	23/64	.063	.031	.460	.076	.070
	AN6	3/8 -24 UNF-3A	.374	.371	.565	.553	.650	.235	.203	7/16		.031	.523	.106	.070
	AN7	7/16-20 UNF-3A	.437	.433	.627	.615	.720	.266	.234	31/64	.063	.031	.585	.106	.070
	AN8	1/2"-20 UNF-3A	.499	.495	.752	.740	.870	.297	.265	39/64		.031	.710	.106	.070
	AN9	9/16-18 UNF-3A	.562	.558	.877	.865	1.010	.328	.296	21/32		.046	.835	.141	.070
	AN10	5/8 -18 UNF-3A	.624	.620	.940	.928	1.090	.360	.328	47/64	.078	.046	.898	.141	.070
	AN12	3/4 -16 UNF-3A	.749	.744	1.066	1.053	1.230	.422	.390	7/8		.046	1.023	.141	.070
	AN14	7/8 -14 UNF-3A	.874	.869	1.253	1.240	1.440	.485	.453	63/64		.062	1.210	.141	.070
(d)	AN16	1 -14 NF-3A	.999	.993	1.441	1.428	1.660	.547	.515	1-3/32	.094	.062	1.398	.141	.070
	AN17	1 -12 UNF-3A	.999	.993	1.441	1.428	1.660	.547	.515	1-3/32	.094	.062	1.398	.141	.070
	AN18	1-1/8 -12 UNF-3A	1.124	1.118	1.628	1.615	1.880	.610	.578	1-3/16		.078	1.585	.141	.070
	AN20	1-1/4 -12 UNF-3A	1.249	1.243	1.815	1.802	2.090	.672	.640	1-3/8	.110	.078	1.772	.141	.070

SEE SHEET 3 FOR NOTE (b).



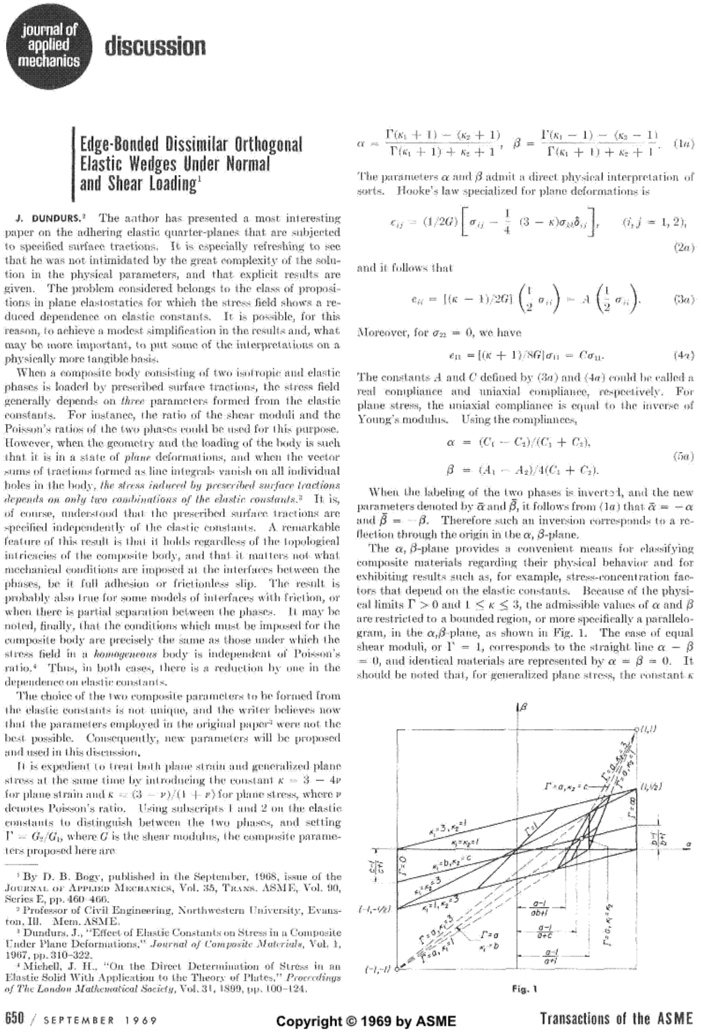
ASTM Steel Pipe Specifications

- A74 - A74-98 - Specification for Cast Iron Soil Pipe and Fittings
- A106 - A106-99e1 - Specification for Seamless Carbon Steel Pipe for High-Temperature Service
- A126 - A126-95e1 - Specification for Grey Iron Castings for Valves, Flanges, and Pipe Fittings
- A134 - A134-96 - Specification for Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and Over)
- A135 - A135-97c - Specification for Electric-Resistance-Welded Steel Pipe
- A139 - A139-96e1 - Specification for Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over)

And many more!!

Journals

- Peer reviewed research
  - Very detailed, well documented and technically oriented!



journal of applied mechanics discussion

Edge-Bonded Dissimilar Orthogonal Elastic Wedges Under Normal and Shear Loading[1]

J. DUNDURS.[2] The author has presented a most interesting paper on the adhering elastic quarter-planes that are subjected to specified surface tractions. It is especially refreshing to see that he was not intimidated by the great complexity of the solution in the physical parameters, and that explicit results are given. The problem considered belongs to the class of propositions in plane elastostatics for which the stress field shows a reduced dependence on elastic constants. It is possible, for this reason, to achieve a modest simplification in the results and, what may be more important, to put some of the interpretations on a physically more tangible basis.

When a composite body consisting of two isotropic and elastic phases is loaded by prescribed surface tractions, the stress field generally depends on *three* parameters formed from the elastic constants. For instance, the ratio of the shear moduli and the Poisson's ratios of the two phases could be used for this purpose. However, when the geometry and the loading of the body is such that it is in a state of *plane* deformations, and when the vector sums of tractions formed as line integrals vanish on all individual holes in the body, *the stress induced by prescribed surface tractions depends on only two combinations of the elastic constants.*[3] It is, of course, understood that the prescribed surface tractions are specified independently of the elastic constants. A remarkable feature of this result is that it holds regardless of the topological intricacies of the composite body, and that it matters not what mechanical conditions are imposed at the interfaces between the phases, be it full adhesion or frictionless slip. The result is probably also true for some models of interfaces with friction, or when there is partial separation between the phases. It may be noted, finally, that the conditions which must be imposed for the composite body are precisely the same as those under which the stress field in a *homogeneous* body is independent of Poisson's ratio.[4] Thus, in both cases, there is a reduction by one in the dependence on elastic constants.

The choice of the two composite parameters to be formed from the elastic constants is not unique, and the writer believes now that the parameters employed in the original paper[3] were not the best possible. Consequently, new parameters will be proposed and used in this discussion.

It is expedient to treat both plane strain and generalized plane stress at the same time by introducing the constant $\kappa = 3 - 4\nu$ for plane strain and $\kappa = (3 - \nu)/(1 + \nu)$ for plane stress, where ν denotes Poisson's ratio. Using subscripts 1 and 2 on the elastic constants to distinguish between the two phases, and setting $\Gamma = G_2/G_1$, where G is the shear modulus, the composite parameters proposed here are

$$\alpha = \frac{\Gamma(\kappa_1 + 1) - (\kappa_2 + 1)}{\Gamma(\kappa_1 + 1) + \kappa_2 + 1}, \quad \beta = \frac{\Gamma(\kappa_1 - 1) - (\kappa_2 - 1)}{\Gamma(\kappa_1 + 1) + \kappa_2 + 1}. \quad (1a)$$

The parameters α and β admit a direct physical interpretation of sorts. Hooke's law specialized for plane deformations is

$$\epsilon_{ij} = (1/2G)\left[\sigma_{ij} - \frac{1}{4}(3 - \kappa)\sigma_{kk}\delta_{ij}\right], \quad (i, j = 1, 2), \quad (2a)$$

and it follows that

$$e_{ii} = [(\kappa - 1)/2G]\left(\frac{1}{2}\sigma_{ii}\right) = A\left(\frac{1}{2}\sigma_{ii}\right). \quad (3a)$$

Moreover, for $\sigma_{22} = 0$, we have

$$e_{11} = [(\kappa + 1)/8G]\sigma_{11} = C\sigma_{11}. \quad (4a)$$

The constants A and C defined by (3a) and (4a) could be called a real compliance and uniaxial compliance, respectively. For plane stress, the uniaxial compliance is equal to the inverse of Young's modulus. Using the compliances,

$$\alpha = (C_1 - C_2)/(C_1 + C_2),$$
$$\beta = (A_1 - A_2)/4(C_1 + C_2). \quad (5a)$$

When the labeling of the two phases is inverted, and the new parameters denoted by $\bar{\alpha}$ and $\bar{\beta}$, it follows from (1a) that $\bar{\alpha} = -\alpha$ and $\bar{\beta} = -\beta$. Therefore such an inversion corresponds to a reflection through the origin in the α, β-plane.

The α, β-plane provides a convenient means for classifying composite materials regarding their physical behavior and for exhibiting results such as, for example, stress-concentration factors that depend on the elastic constants. Because of the physical limits $\Gamma > 0$ and $1 \leq \kappa \leq 3$, the admissible values of α and β are restricted to a bounded region, or more specifically a parallelogram, in the α, β-plane, as shown in Fig. 1. The case of equal shear moduli, or $\Gamma = 1$, corresponds to the straight line $\alpha - \beta = 0$, and identical materials are represented by $\alpha = \beta = 0$. It should be noted that, for generalized plane stress, the constant κ

Fig. 1

[1] By D. B. Bogy, published in the September, 1968, issue of the Journal of Applied Mechanics, Vol. 35, Trans. ASME, Vol. 90, Series E, pp. 460–466.

[2] Professor of Civil Engineering, Northwestern University, Evanston, Ill. Mem. ASME.

[3] Dundurs, J., "Effect of Elastic Constants on Stress in a Composite Under Plane Deformations," *Journal of Composite Materials*, Vol. 1, 1967, pp. 310–322.

[4] Michell, J. H., "On the Direct Determination of Stress in an Elastic Solid With Application to the Theory of Plates," *Proceedings of The London Mathematical Society*, Vol. 31, 1899, pp. 100–124.

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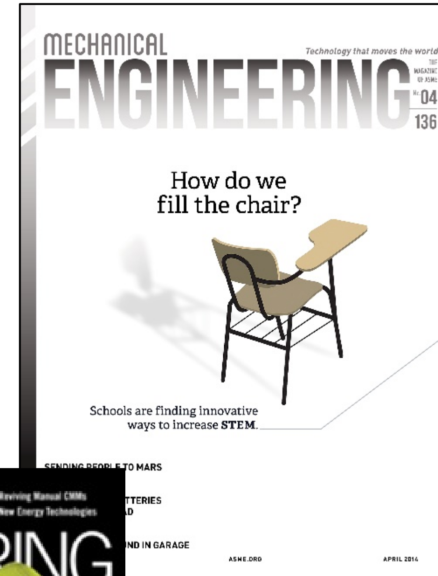
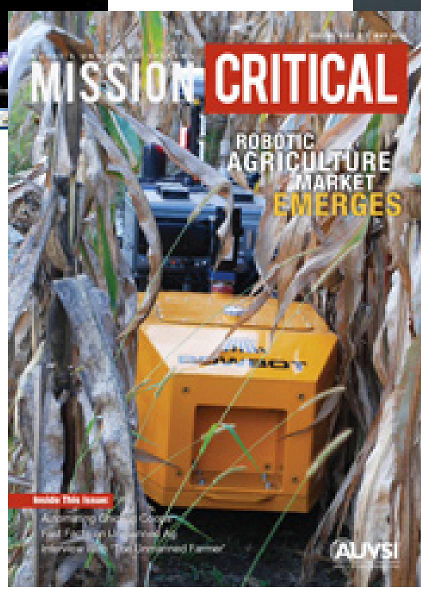
Trade Publications

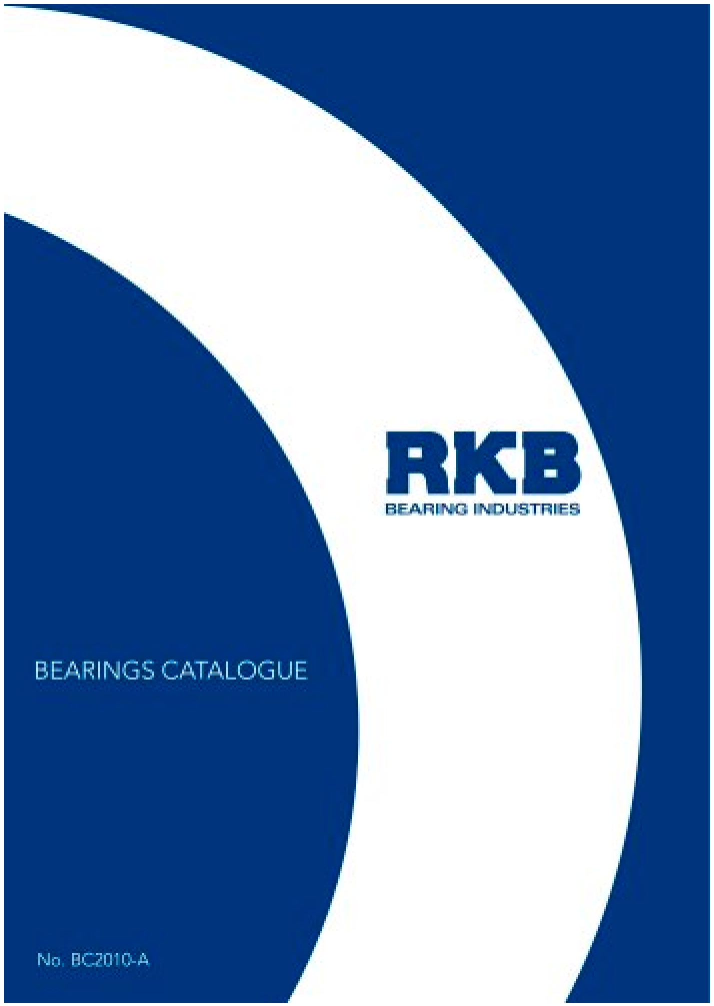
- Published by societies and trade organizations

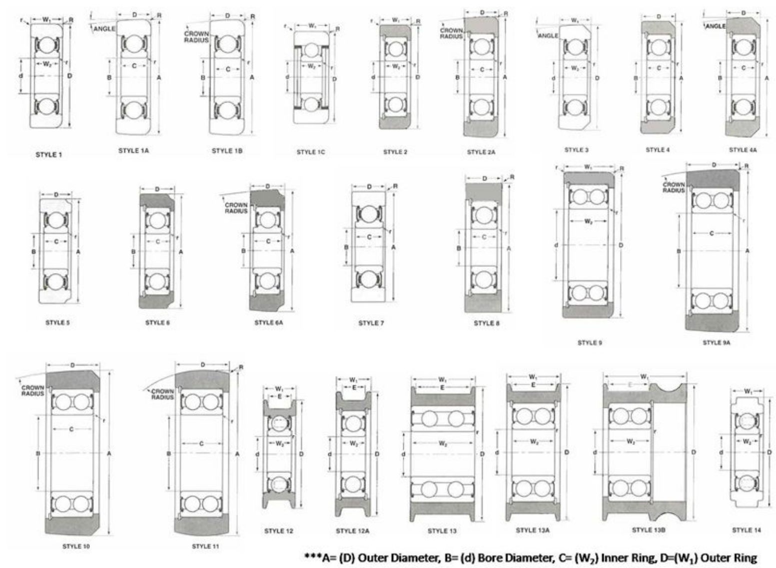


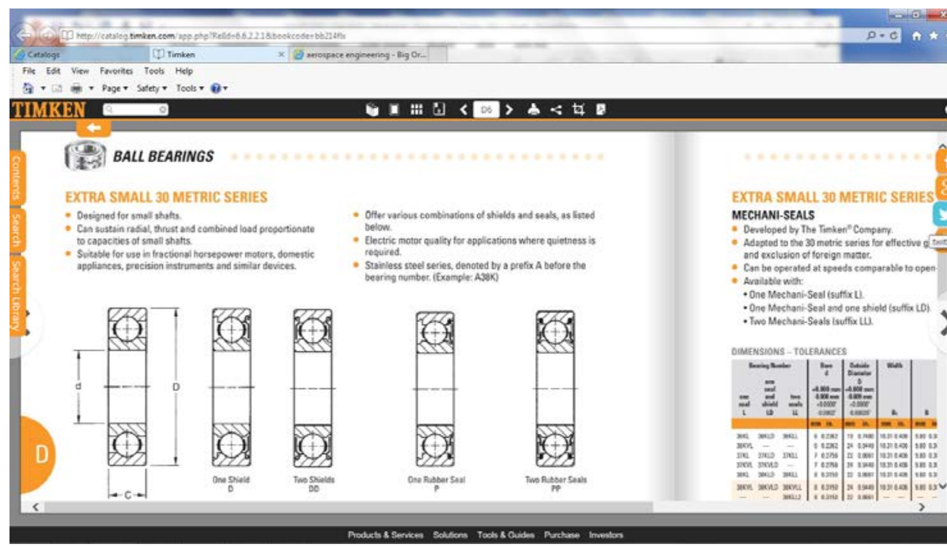


Vendor Publications

- Company documents, catalogs, papers, data sheets and other information







Healthy Skepticism

- Because I say so
- Because he said so
- Because they say so
- Because this similar thing did X,Y,Z

Relying on outside sources
Need to verify truth & relevance

- Because math analysis says…
- Because computer simulations say…

Good
Uses your engineering skills

- Because the prototype did…
- Because I built it already and look - it works!

Best
Justification on Real Physics