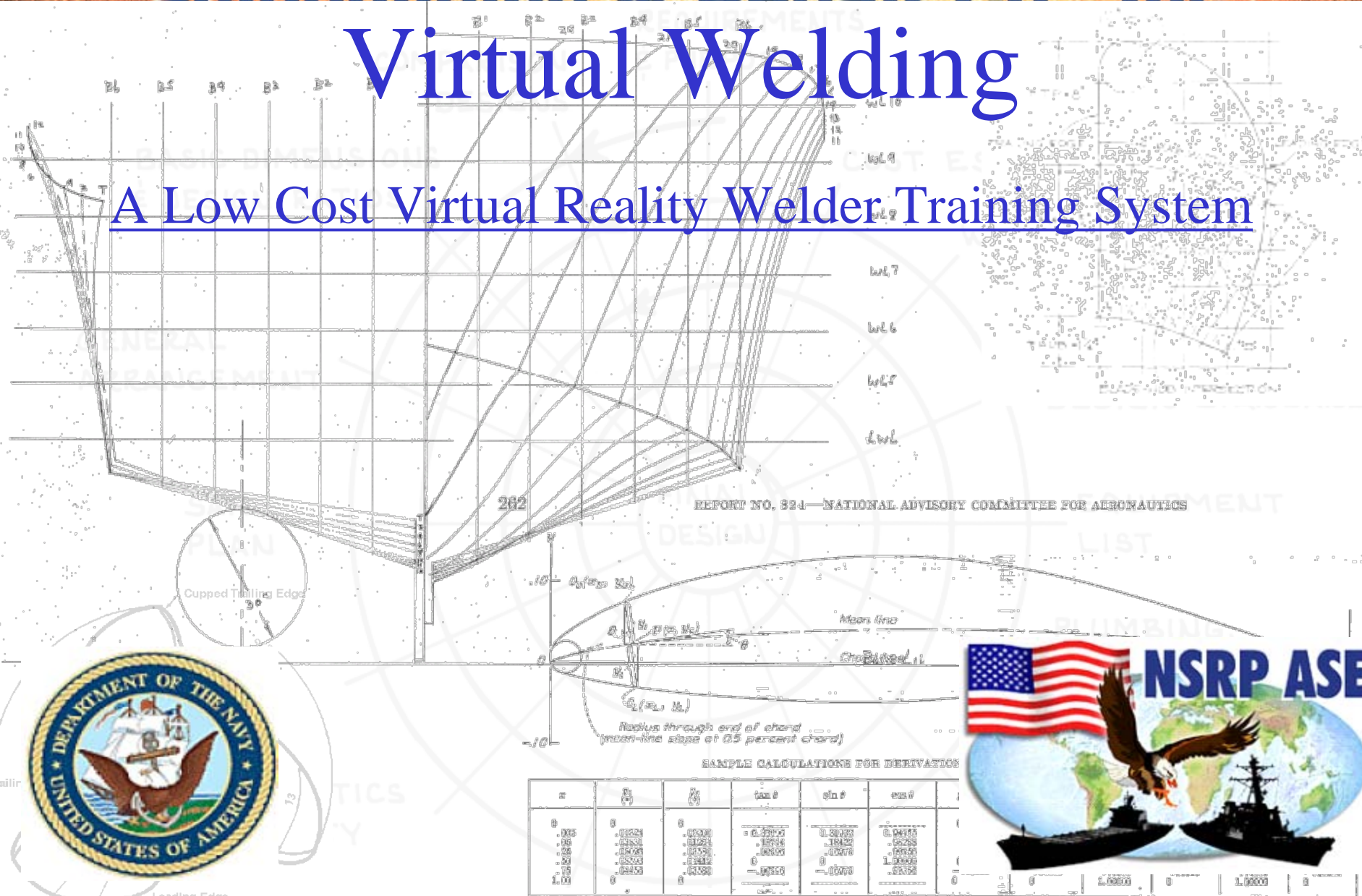
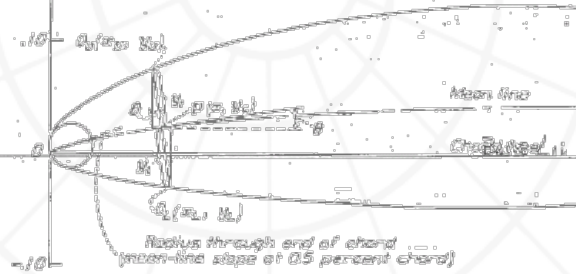


## Virtual Welding

### A Low Cost Virtual Reality Welder Training System



REPORT NO. 324—NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS



SAMPLE CALCULATIONS FOR DERIVATIVES

$x$	$y$	$z$	$\tan \theta$	$\sin \theta$	$\cos \theta$
0.05	0.0024	0.0000	0.0480	0.0479	0.9988
0.10	0.0048	0.0000	0.0960	0.0958	0.9954
0.15	0.0072	0.0000	0.1440	0.1437	0.9893
0.20	0.0096	0.0000	0.1920	0.1916	0.9806
0.25	0.0120	0.0000	0.2400	0.2395	0.9694
0.30	0.0144	0.0000	0.2880	0.2873	0.9558
0.35	0.0168	0.0000	0.3360	0.3351	0.9399
0.40	0.0192	0.0000	0.3840	0.3829	0.9218
0.45	0.0216	0.0000	0.4320	0.4307	0.9016
0.50	0.0240	0.0000	0.4800	0.4783	0.8794
0.55	0.0264	0.0000	0.5280	0.5257	0.8552
0.60	0.0288	0.0000	0.5760	0.5729	0.8291
0.65	0.0312	0.0000	0.6240	0.6199	0.8012
0.70	0.0336	0.0000	0.6720	0.6666	0.7717
0.75	0.0360	0.0000	0.7200	0.7131	0.7309
0.80	0.0384	0.0000	0.7680	0.7591	0.6797
0.85	0.0408	0.0000	0.8160	0.8046	0.6185
0.90	0.0432	0.0000	0.8640	0.8496	0.5480
0.95	0.0456	0.0000	0.9120	0.8941	0.4690
1.00	0.0480	0.0000	0.9600	0.9381	0.3827

\* Thickness distribution obtained from estimate of the NACA 035-015 airfoil.  
 † Ordinates of the mean line, 0.5 of the ordinates for  $c_m=1.0$ .  
 ‡ Slope of radius through end of chord.



# BENDER

Shipbuilding & Repair Co., Inc.

## Virtual Welding Project Team



0.075	0.0824	0.0900	0.0975	0.1050	0.1125
0.08	0.0850	0.0900	0.0950	0.1000	0.1050
0.08	0.0850	0.0900	0.0950	0.1000	0.1050
0.08	0.0850	0.0900	0.0950	0.1000	0.1050
0.08	0.0850	0.0900	0.0950	0.1000	0.1050
0.08	0.0850	0.0900	0.0950	0.1000	0.1050

\* Thickness distribution obtained from estimate of the NACA 035-015 airfoil.  
 † Coordinates of the mean line, 0.8 of the ordinates for  $c_m=1.0$ .  
 ‡ Slope of radius through end of chord.

# BENDER

Shipbuilding & Repair Co. Inc.

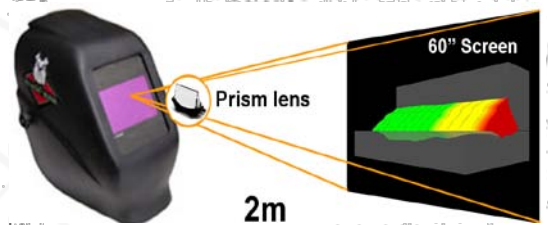
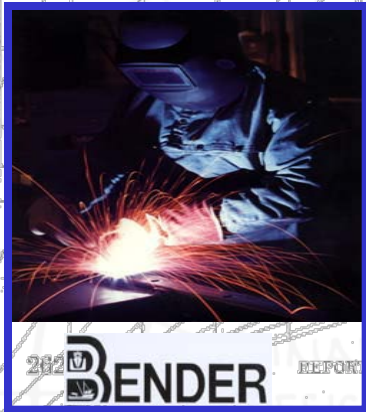
US NAVY



## 75% Manual GMAW

### Commercial Welding:

- 1.3M Hours of Welding per Hull
- Improve weld pool graphics
- Improve sound
- Add real-time feedback

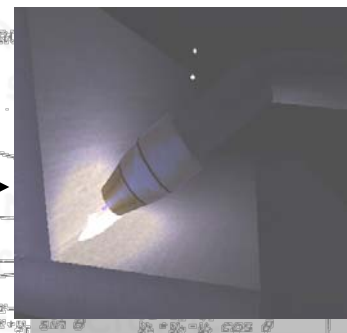


*In Helmet – Heads-up Display – Video & Audio*

## 25% Manual GMAW

### Submarine Welding:

- 1.3M Hours of Welding per Hull
- Improve weld pool graphics
- Improve sound
- Add real-time feedback
- Help welder correct torch orientation or travel speed on the fly



PROPOSED WORK

# BENDER

Shipbuilding & Repair Co. Inc.

US NAVY



OBJECTIVE

## Virtual Training

Maximize training efficiency, reduce training time, reduce materials cost, automated immediate feedback, screening tool.

## Low Cost

Utilize new advanced sensing and fast/accurate artificial intelligence technology to reduce workstation cost.

BENEFITS

## SIM WELDER™

### High Cost Virtual Welding

Developed to train Brain Surgeons

- High precision, high cost tools
- Massive computing requirements
- Clean room type fixturing
- Research demonstrated feasibility



### Proven feasibility of V. R. for welder training

- U.S. Army Funded Testing Program
- Conducted by South Dakota School of Mines
- 60% reduction in actual welding time
- 70%+ reduction in consumables
- 40% reduction in total training time
- Improved welder skills

### ONR Analysis of data from GDEB

- Reduce gas metal arc welder training costs at GDEB by \$81K annually
- increase overall welder productivity by \$1.3M per Submarine hull
- increase gas metal arc welder productivity alone will result in a \$325K savings per submarine hull



### Analysis of Virtual Welder

Virtual Welder can train welders

- Reduced cost of training
- Improve skill of welders
- Reduce cost of welding ships





## Hardware Developments

- Increased the number of Wii remotes
- Altered the targeting of the remotes

The **Wii Remote**, is the primary controller for Nintendo's Wii console. A main feature of the Wii Remote is its motion sensing capability, which allows the user to interact with and manipulate items on screen via movement and pointing through the use of accelerometer and optical sensor technology.



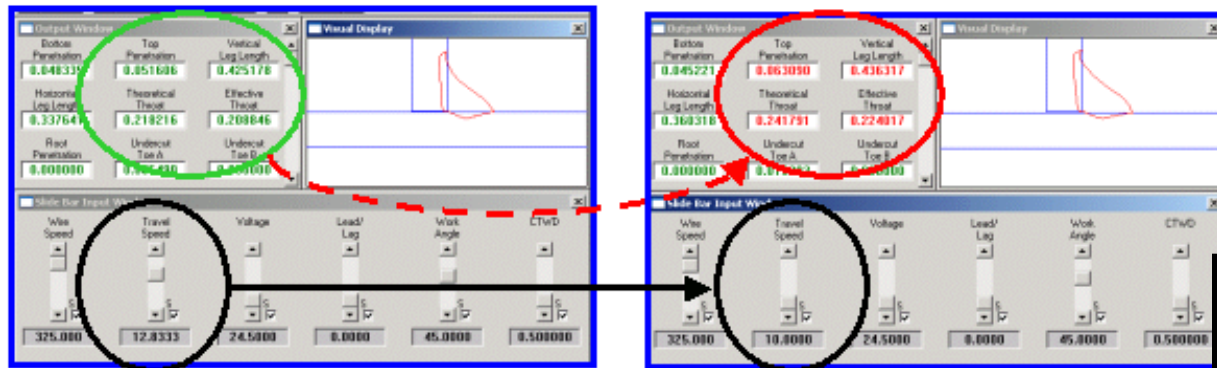
SAMPLE CALCULATIONS FOR DERIVATION OF THE

$\alpha$	$\sin \alpha$	$\cos \alpha$	$\tan \alpha$	$\csc \alpha$	$\sec \alpha$	$\cot \alpha$
0	0.0000	1.0000	0.0000	∞	1.0000	∞
10	0.1736	0.9848	0.1763	5.7590	1.0154	5.6713
20	0.3420	0.9397	0.3640	2.9238	1.0642	2.7475
30	0.5000	0.8660	0.5774	2.0000	1.1547	1.7321
45	0.7071	0.7071	1.0000	1.4142	1.4142	1.0000
60	0.8660	0.5000	1.7321	1.1547	1.0000	0.5774
70	0.9397	0.3420	2.7475	1.0642	1.0154	0.3420
80	0.9848	0.1736	5.6713	1.0154	1.0642	0.1736
90	1.0000	0.0000	∞	∞	1.0000	0.0000

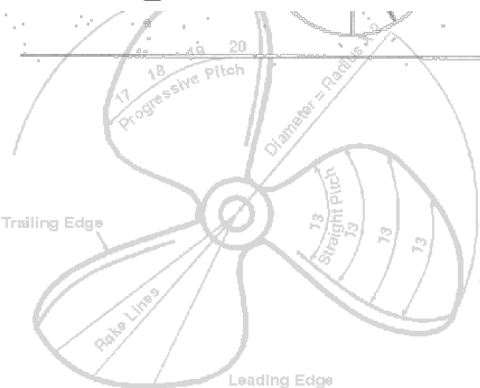
\* Thickness distribution obtained from estimates of the NIACA 035-015 airfoil.  
 † Coordinates of the mean line, 0.8 of the ordinates for  $\alpha=10^\circ$ .  
 ‡ Slope of radius through end of chord.

## NAMES Software

- Used in over 200 automotive plants to monitor weld quality.



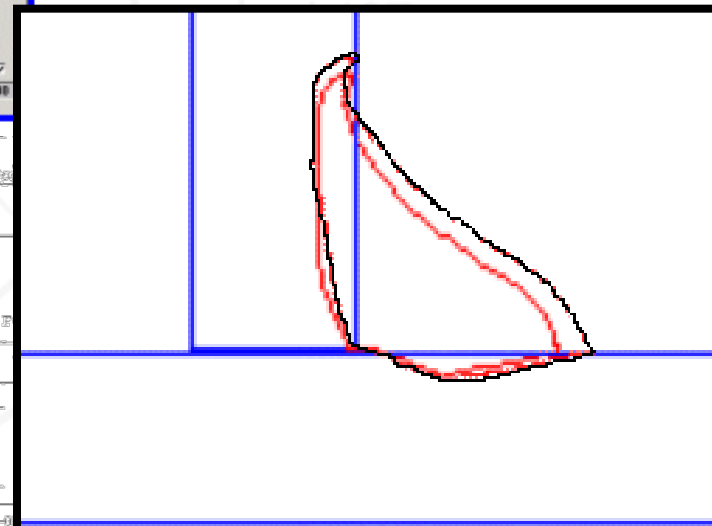
L. ADVISORY COMMITTEE FOR AERONAUTICS



SAMPLE CALCULATIONS

$\alpha$	$\sin \alpha$	$\cos \alpha$	$\tan \alpha$	$\sin^2 \alpha$
0	0.0000	1.0000	0.0000	0.0000
0.05	0.0087	0.9962	0.0087	0.000075
0.10	0.0174	0.9848	0.0174	0.000302
0.15	0.0261	0.9709	0.0261	0.000681
0.20	0.0344	0.9597	0.0344	0.001183
0.25	0.0421	0.9413	0.0421	0.001772
0.30	0.0491	0.9174	0.0491	0.002410
0.35	0.0556	0.8882	0.0556	0.003091
0.40	0.0616	0.8539	0.0616	0.003816

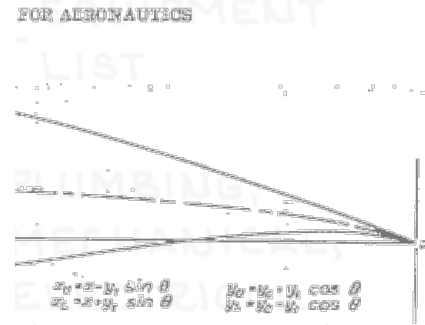
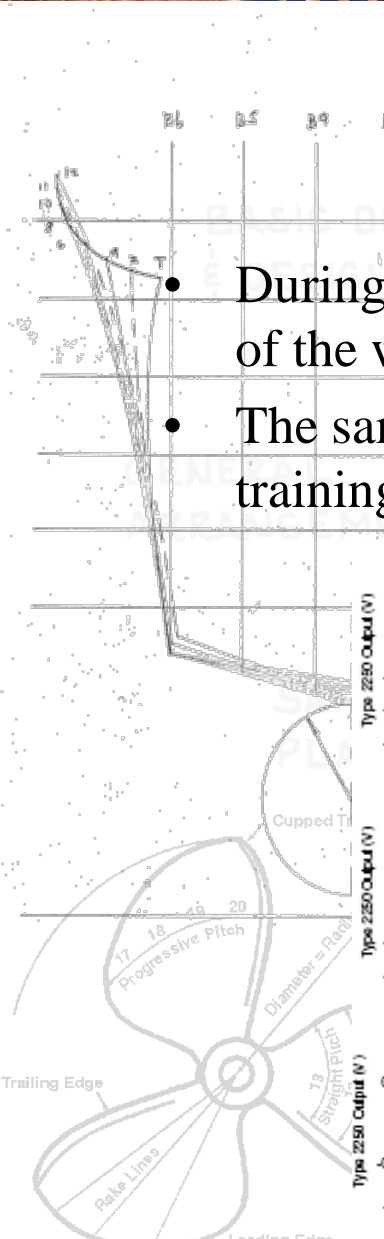
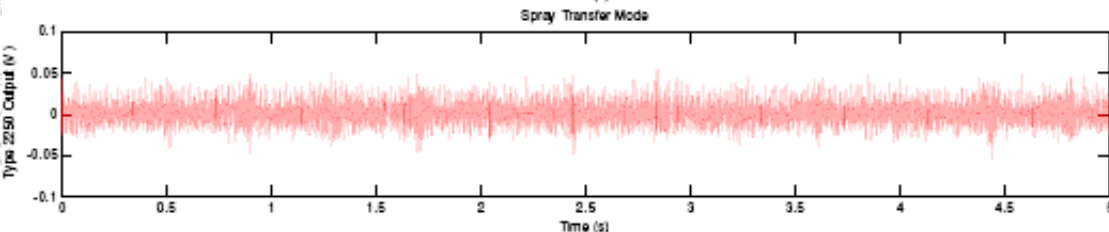
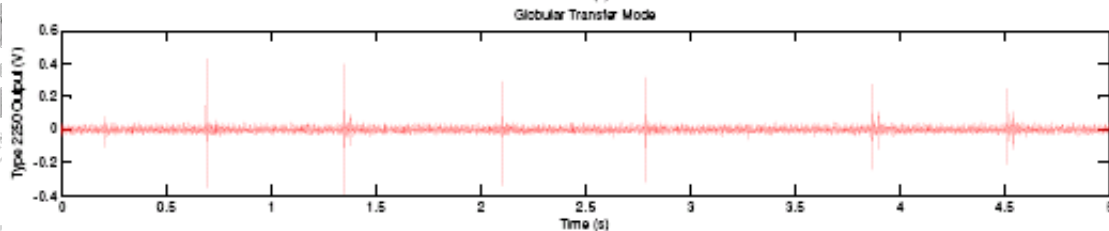
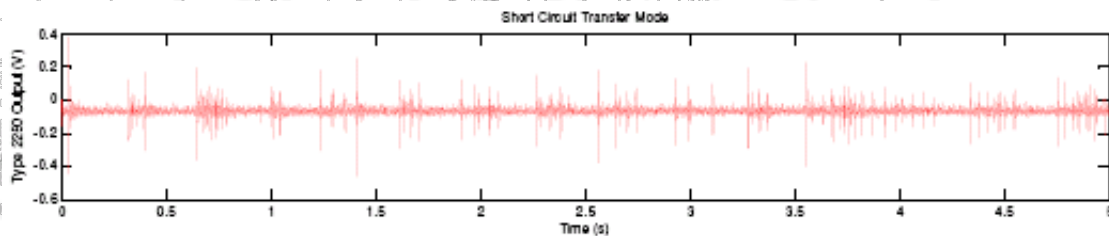
\* Thickness distribution obtained from estimates of the NACA 03,5-D  
 \* Coordinates of the mean line, 0.8 of the ordinates for  $\alpha=1.0$ .  
 \* Slope of radius through end of chord.





## VW Sound Control

- During the weld tests Audio was sampled at the same 20Hz as the rest of the weld parameters
- The sample will be tied to the parameters and reproduced during the training to match what the weld is doing.



N3-03,  $\alpha=14$  AIRFOIL

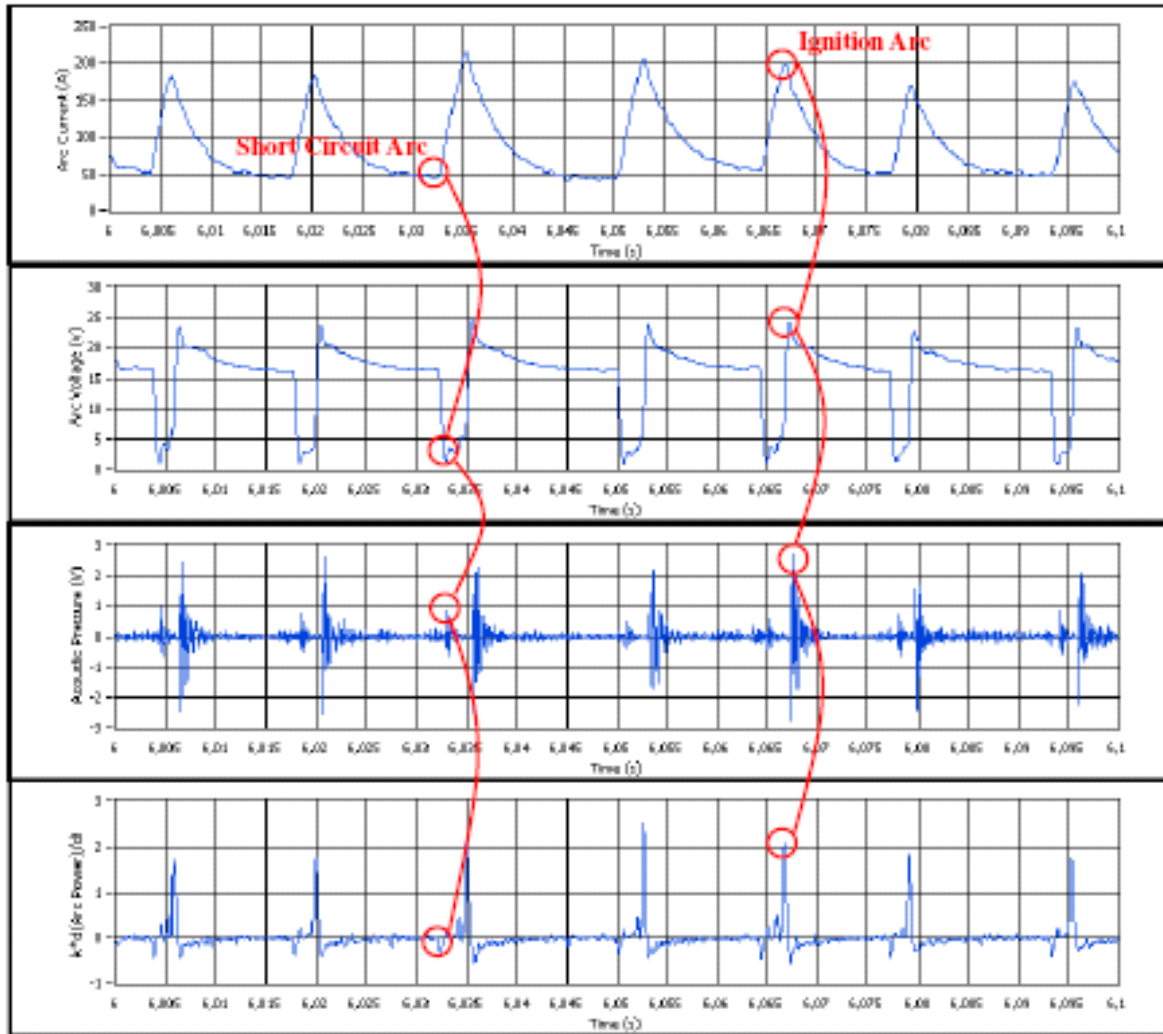
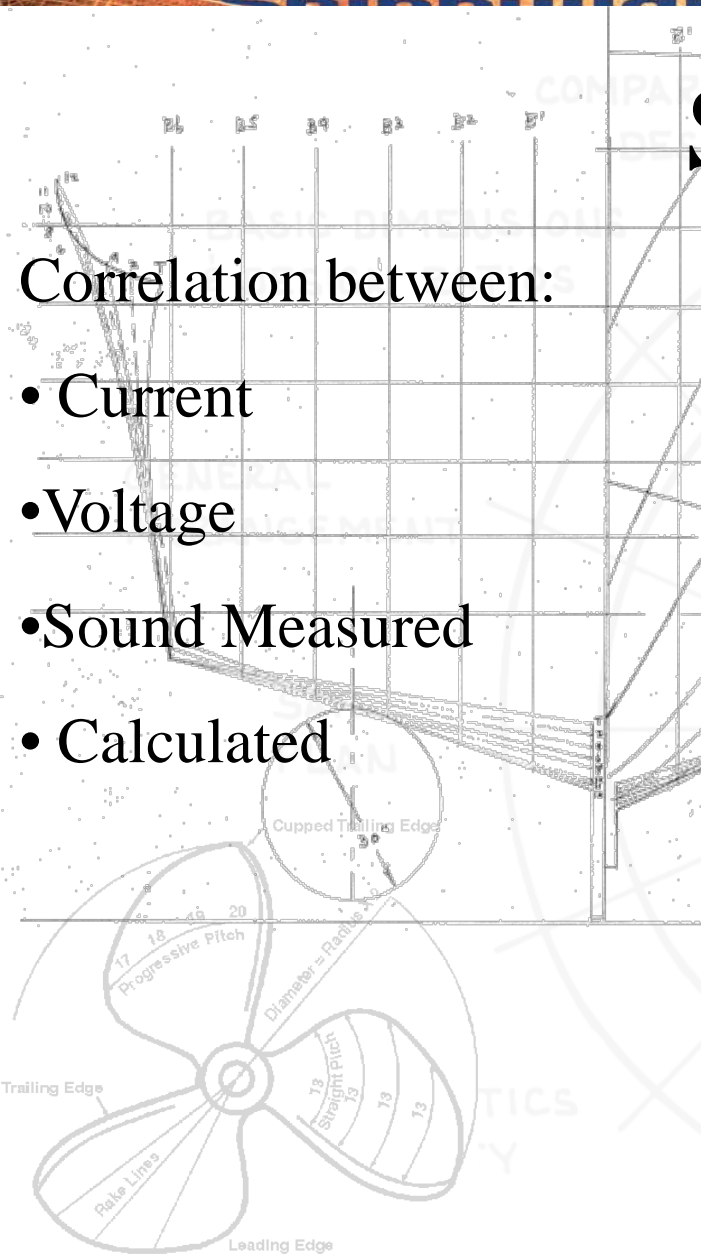
	X0	Y0	X1	Y1
0	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000
7	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0000
11	0.0000	0.0000	0.0000	0.0000
12	0.0000	0.0000	0.0000	0.0000
13	0.0000	0.0000	0.0000	0.0000
14	0.0000	0.0000	0.0000	0.0000
15	0.0000	0.0000	0.0000	0.0000
16	0.0000	0.0000	0.0000	0.0000
17	0.0000	0.0000	0.0000	0.0000
18	0.0000	0.0000	0.0000	0.0000
19	0.0000	0.0000	0.0000	0.0000
20	0.0000	0.0000	0.0000	0.0000
21	0.0000	0.0000	0.0000	0.0000
22	0.0000	0.0000	0.0000	0.0000
23	0.0000	0.0000	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.0000
25	0.0000	0.0000	0.0000	0.0000
26	0.0000	0.0000	0.0000	0.0000
27	0.0000	0.0000	0.0000	0.0000
28	0.0000	0.0000	0.0000	0.0000
29	0.0000	0.0000	0.0000	0.0000
30	0.0000	0.0000	0.0000	0.0000
31	0.0000	0.0000	0.0000	0.0000
32	0.0000	0.0000	0.0000	0.0000
33	0.0000	0.0000	0.0000	0.0000
34	0.0000	0.0000	0.0000	0.0000
35	0.0000	0.0000	0.0000	0.0000
36	0.0000	0.0000	0.0000	0.0000
37	0.0000	0.0000	0.0000	0.0000
38	0.0000	0.0000	0.0000	0.0000
39	0.0000	0.0000	0.0000	0.0000
40	0.0000	0.0000	0.0000	0.0000
41	0.0000	0.0000	0.0000	0.0000
42	0.0000	0.0000	0.0000	0.0000
43	0.0000	0.0000	0.0000	0.0000
44	0.0000	0.0000	0.0000	0.0000
45	0.0000	0.0000	0.0000	0.0000
46	0.0000	0.0000	0.0000	0.0000
47	0.0000	0.0000	0.0000	0.0000
48	0.0000	0.0000	0.0000	0.0000
49	0.0000	0.0000	0.0000	0.0000
50	0.0000	0.0000	0.0000	0.0000

\* Thickness distribution obtained from ordinate of the NACA 03-03 airfoil.  
 † Ordinate of the mean line, 0.8 of the ordinate for  $\alpha=14$ .  
 ‡ Slope of rake through end of chord.

## Sound Data

Correlation between:

- Current
- Voltage
- Sound Measured
- Calculated



## Sound Related to Defects

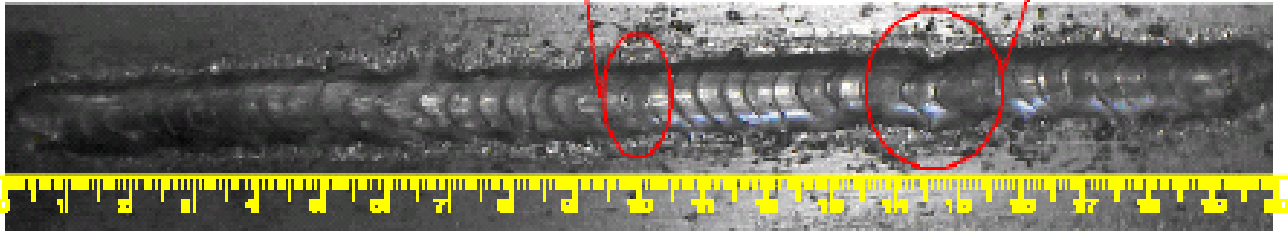
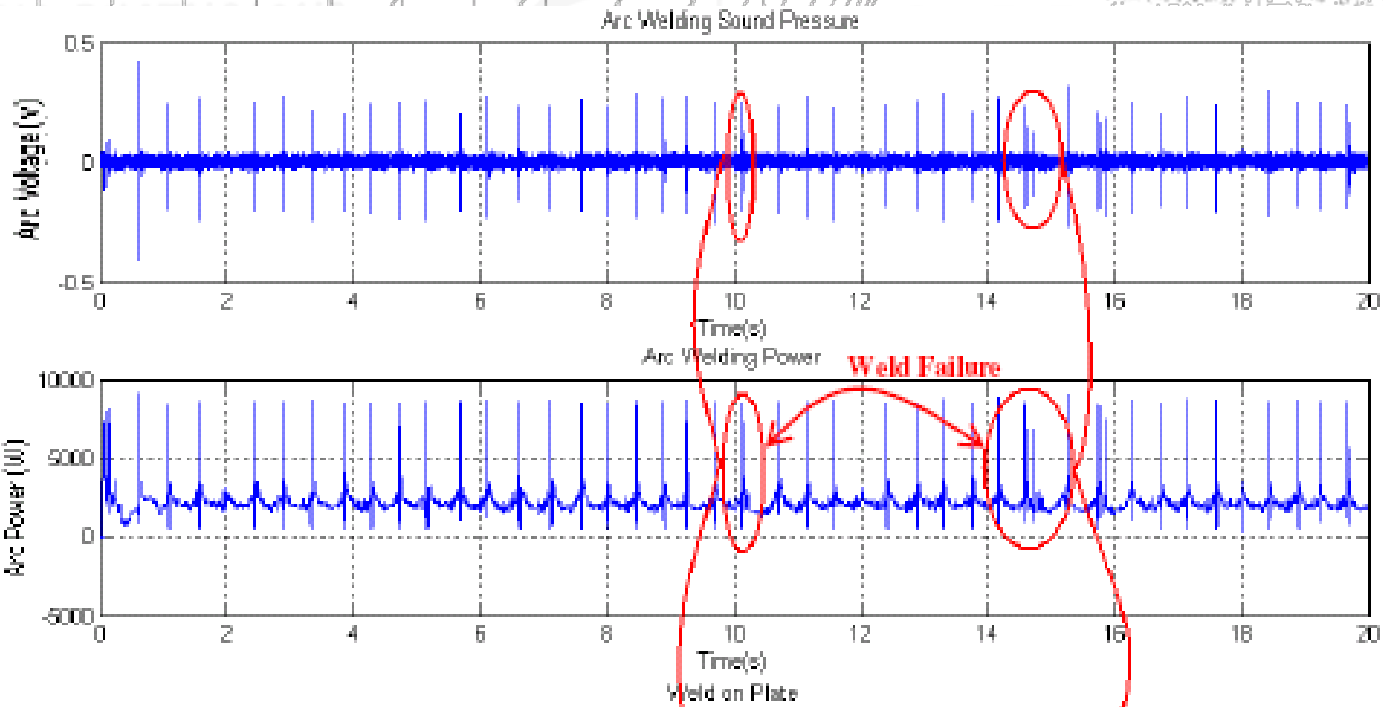
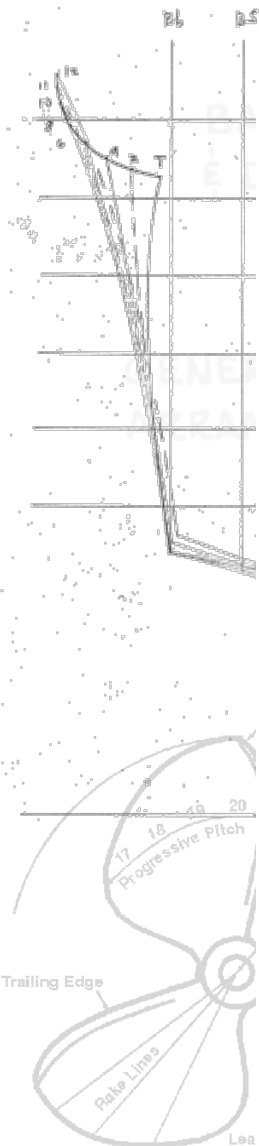


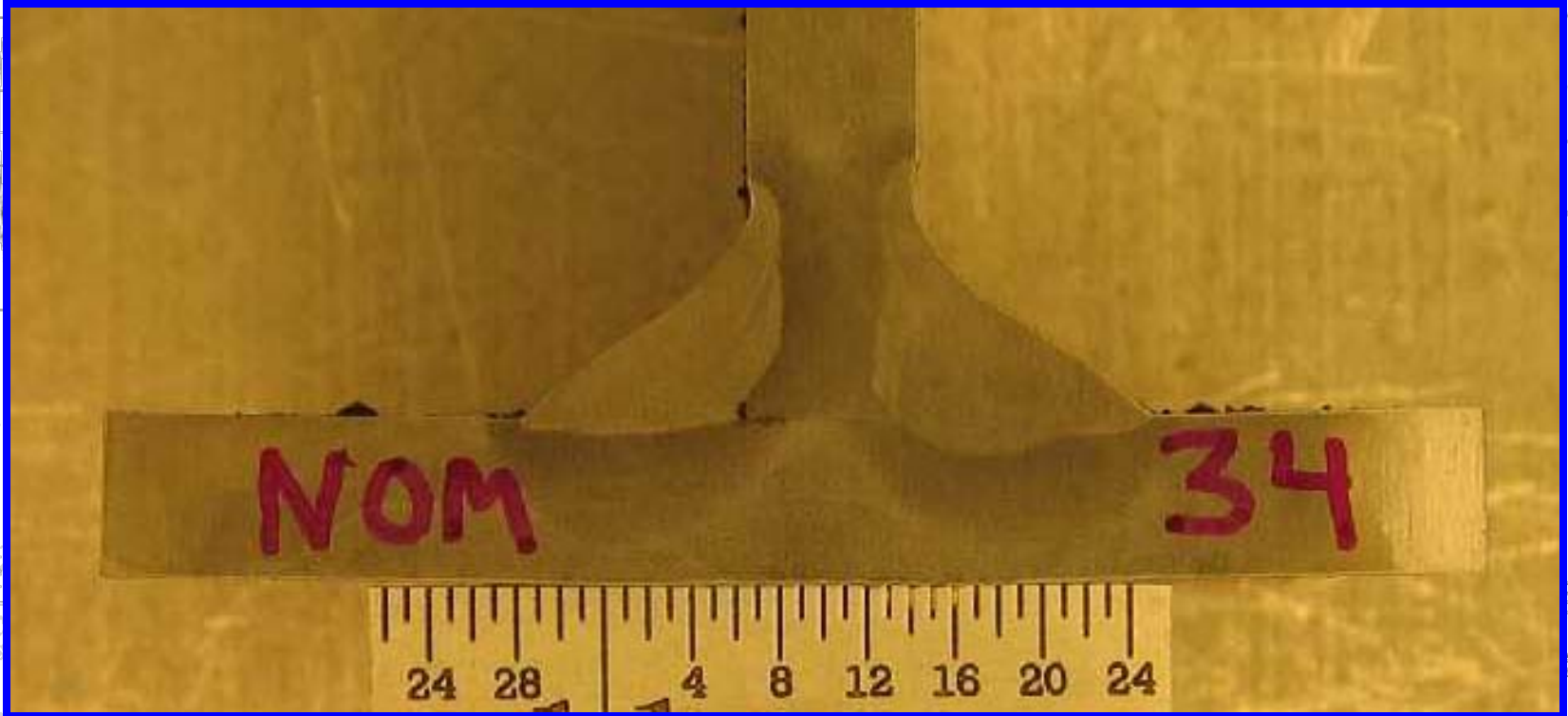
Figure – 10 Weld Defect Identification of power and sound pressure (Test 8)



$\theta_1$	$\theta_2$
0	0
0.0053	-0.0165
0.0116	-0.0291
0.0228	-0.0433
0.0008	-0.0151
0.0152	-0.0553
0.0660	0

\* Slope of radius through end of chord.

## Weld Sample



SAMPLE CALCULATIONS FOR DERIVATION OF THE NACA 230-018 AIRFOIL

$x$	$\frac{y}{c}$	$\frac{y'}{c}$	$\tan \theta$	$\sin \theta$	$\cos \theta$	$\frac{y}{c} \sin \theta$	$\frac{y'}{c} \cos \theta$	$\frac{y}{c}$	$\frac{y'}{c}$	$\frac{y}{c}$	$\frac{y'}{c}$
0	0	0	0	0	1	0	0	0	0	0	0
.05	.0124	.0200	0.2000	0.1961	0.9808	0.0244	0.0396	0	0.0443	0	0.0553
.10	.0248	.0400	0.4000	0.3919	0.9211	0.0496	0.0792	0	0.0886	0	0.1106
.15	.0372	.0600	0.6000	0.5924	0.8090	0.0748	0.1188	0	0.1275	0	0.1573
.20	.0496	.0800	0.8000	0.7962	0.6042	0.1000	0.1580	0	0.1560	0	0.1960
.25	.0620	.1000	1.0000	0.9999	0.0174	0.1252	0.1972	0	0.1850	0	0.2350
.30	.0744	.1200	1.2000	1.0000	0.0000	0.1504	0.2364	0	0.2238	0	0.2838
.35	.0868	.1400	1.4000	0.9999	-0.0174	0.1756	0.2756	0	0.2616	0	0.3316
.40	.0992	.1600	1.6000	0.9999	-0.0348	0.2008	0.3148	0	0.2994	0	0.3794

\* Thickness distribution obtained from ordinates of the NACA 230-018 airfoil.  
 † Ordinates of the mean line, 0.8 of the ordinates for  $c_m=1.0$ .  
 ‡ Slope of radius through end of chord.







## The Weld Pool

What a welder can actually see while welding. A large key to truly knowing how to weld.

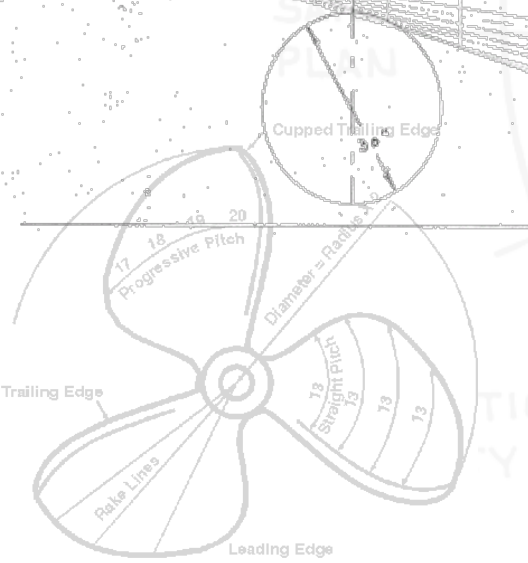


Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X
0.00	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.05	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.10	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.15	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.20	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.25	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.30	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.35	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.40	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.45	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.50	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.55	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.60	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.65	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.70	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.75	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.80	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.85	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.90	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.95	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.00	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

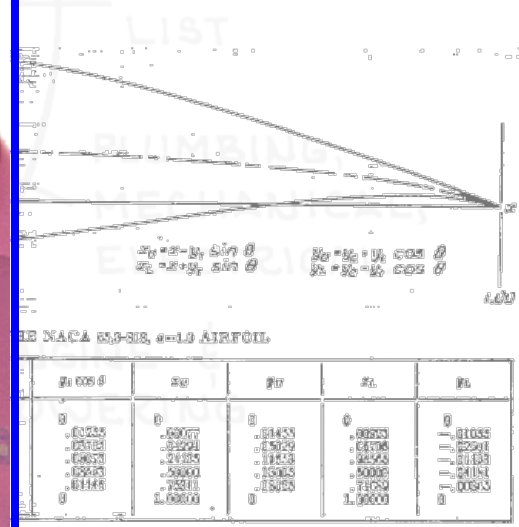
\* Thickness distribution obtained from estimates of the NACA 03,5-015 airfoil.  
 † Ordinates of the mean line, 0.8 of the ordinates for  $c_m=1.0$ .  
 ‡ Slope of radius through end of chord.

## Visual Display

While this task is not due to be completed until well into Phase II, the system will be tested and demonstrated using the dual video glasses inside the helmet. Although it was originally planned to only produce a pseudo-3D display, the glasses have two separate LCD projection displays and software that can accept two different renderings of the scene, offset to produce a virtual 3D image. Consequently, by using the glasses, it appears that it will be possible to generate a virtual 3D image for the Training System.



REPORT NO. 834—NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS



# BENDER

Shipbuilding & Repair Co., Inc.

## Questions



0.075	0.0824	0.0900	0.0975	0.1050	0.1125
0.08	0.0856	0.0912	0.0968	0.1024	0.1080
0.085	0.0904	0.0960	0.1016	0.1072	0.1128
0.09	0.0952	0.1008	0.1064	0.1120	0.1176
0.095	0.1000	0.1056	0.1112	0.1168	0.1224
0.10	0.1048	0.1104	0.1160	0.1216	0.1272
0.105	0.1104	0.1160	0.1216	0.1272	0.1328
0.11	0.1152	0.1208	0.1264	0.1320	0.1376
0.115	0.1200	0.1256	0.1312	0.1368	0.1424
0.12	0.1248	0.1304	0.1360	0.1416	0.1472

\* Thickness distribution obtained from estimate of the NACA 035-015 airfoil.  
 † Ordinates of the mean line, 0.8 of the ordinates for  $c_m=1.0$ .  
 ‡ Slope of radius through end of chord.