VISIBLE WELDING

Reducing *Cost* of Welder Training via Intelligent Video Tools

Project Summary

NSRP RA 1101-11 **May 2016**

Agenda

- Video Tutoring
  - Background
  - Results
  - History
- Future video in shipbuilding
- IR Camera CRDA
  - NSWCCD and Visible Welding

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Background

- The US welder shortage is impacting shipbuilding schedules
- US Navy wants to speed welder training.

Take an idea from Sports Training;

- Use video as a tutoring aid
  - Demo on big-screen to support larger classes
  - Video recording and coaching is a proven technique for sports training, from casual golfers to Olympic elites

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Contributors

- **US Navy NSRP – Major Funding**
- **Visible Welding – Video Technology**
- **Bollinger Shipyards – Testing and Project Mgmt.**
- **Intertest, Inc. – Prototype Fabrication**
- **Miller Electric – Weld Expertise**
- **Fronius USA – Weld Expertise**
- **ESAB USA – Test Support**
- **Manchester College – In-class Testing**
- **Ingalls Shipyard – In-facility Testing**
- **Lafourche Career Ctr. – Testing and Support**
- **TLW Productions – Demo Videos**
- **Applied Thermal Sci. – Weld Testing**

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Project Design Goals

The tools will ideally allow instructor to:

- Show demos on-screen, live or recorded
- Coach student while they weld
- Record student welds
- Playback and review with the student
- Build a library of examples (both good and bad)

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Projected Benefits

- Shorten training time
- Free instructor time
- Reduce production errors by giving welders insights which are normally unseen.

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Final Version – Simple

- Movable camera and PC touch-screen

VISIBLE WELDING

NSRP RESEARCH PROGRAM

Final Configuration

- **WeldWatch close-up camera on movable arm**
- **Touch-screen on similar movable arm**
- **Volt and Amp sensor with real-time, on-screen graphs**
- **Automated recording triggered by weld**
- **Automated replay after weld**
- **Support for library of videos**
- **Optional big-screen TV (HDMI)**

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Almost Hands-off for Lessons

1. Aim the camera at the weld area and auto-focus.
2. Weld anytime, EDU auto-records whenever weld current flows
3. After a weld, EDU replays the recording
4. After replay, EDU returns to live camera view, ready to record.

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Simple Screen and Controls
Real-time Volt-Amps Graph in Main Window

VISIBLE WELDING

NSRP RESEARCH PROGRAM

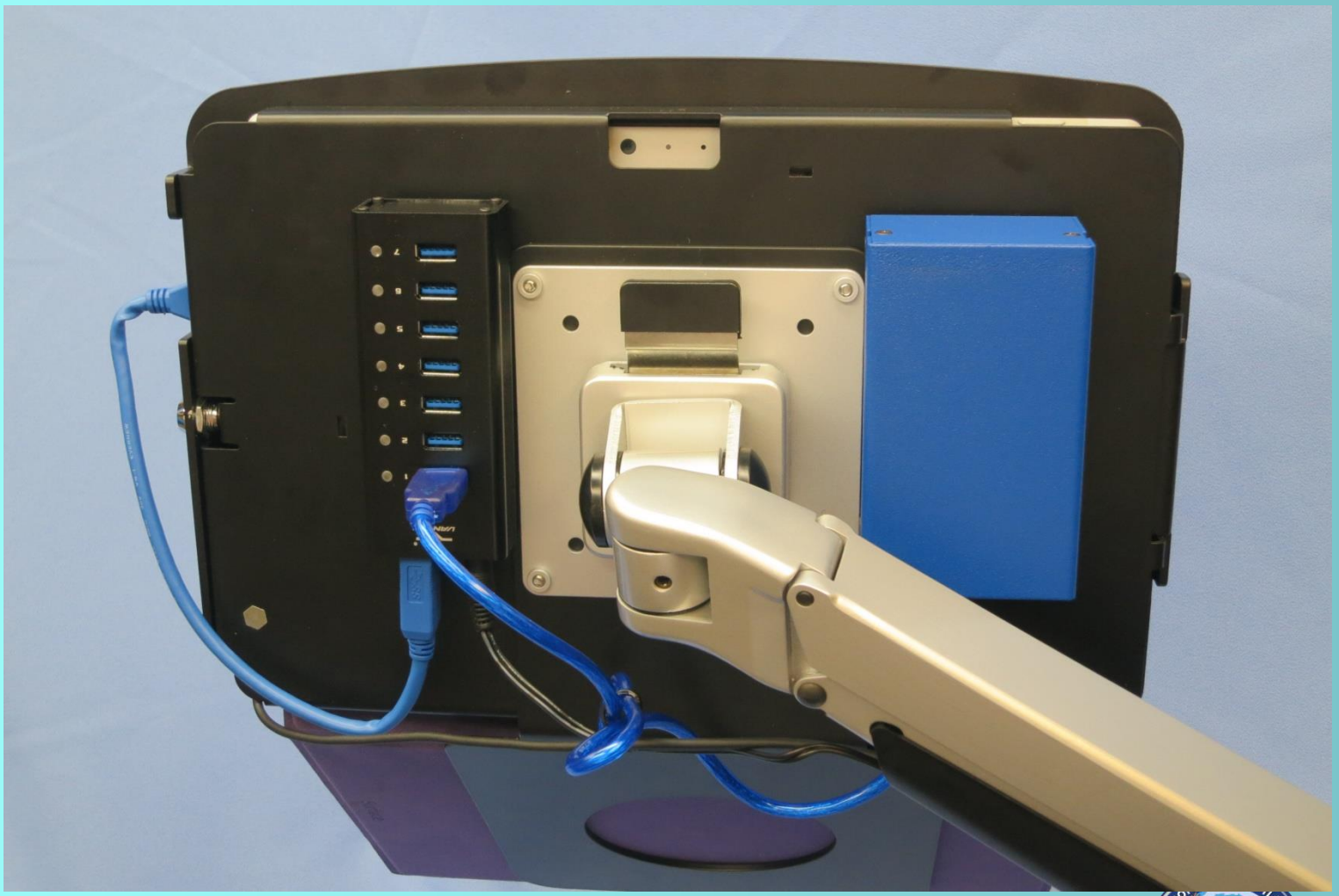
Computer Station

- Microsoft Surface combines touch-screen and PC
- Built-in disk supports library of videos
- HDMI output for large-screen TV
- Volts and Amps sampled 1 kHz with custom USB module

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Blue Volt-Amp Box on Back



VISIBLE WELDING

NSRP RESEARCH PROGRAM

Live Demo on Tour Today

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Result of testing over 2 years

- Alpha & Beta testing at Manchester NH Community College
- Beta testing at Bollinger training facility
- Beta & Final-Configuration testing at HII Ingalls training facility
- Over 100 revisions

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

3 Types of Testing

- Demo Tests

- System Test
- Lessons Experimentation

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

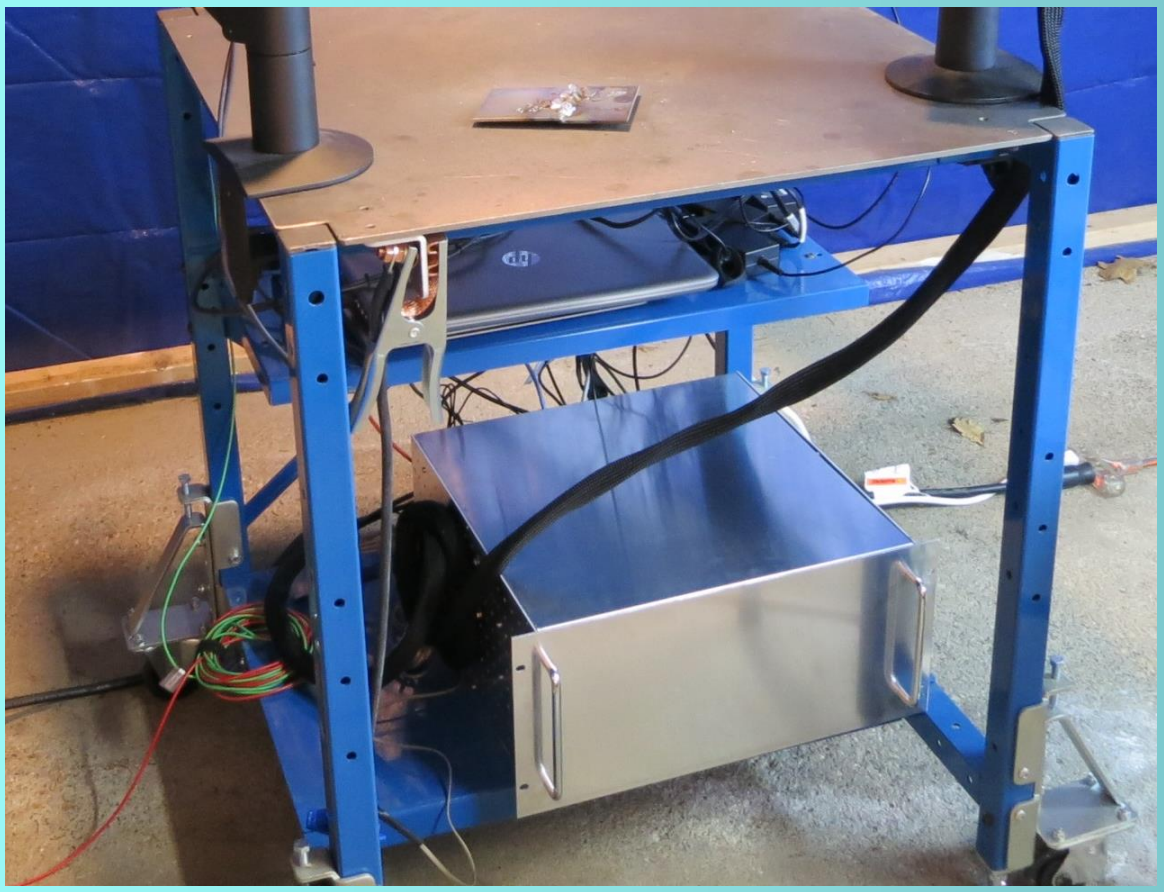
First Tested Station with Domes

VISIBLE WELDING

NSRP

Below Decks

2 PCs and Network Interface Box



VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Features Tested and Removed

- Computer-controlled camera domes
- Wide-view cameras
- Ethernet infrastructure
- Network video recorder
- Multiple on-screen videos
- Cluttered on-screen controls
- Video VR goggles

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

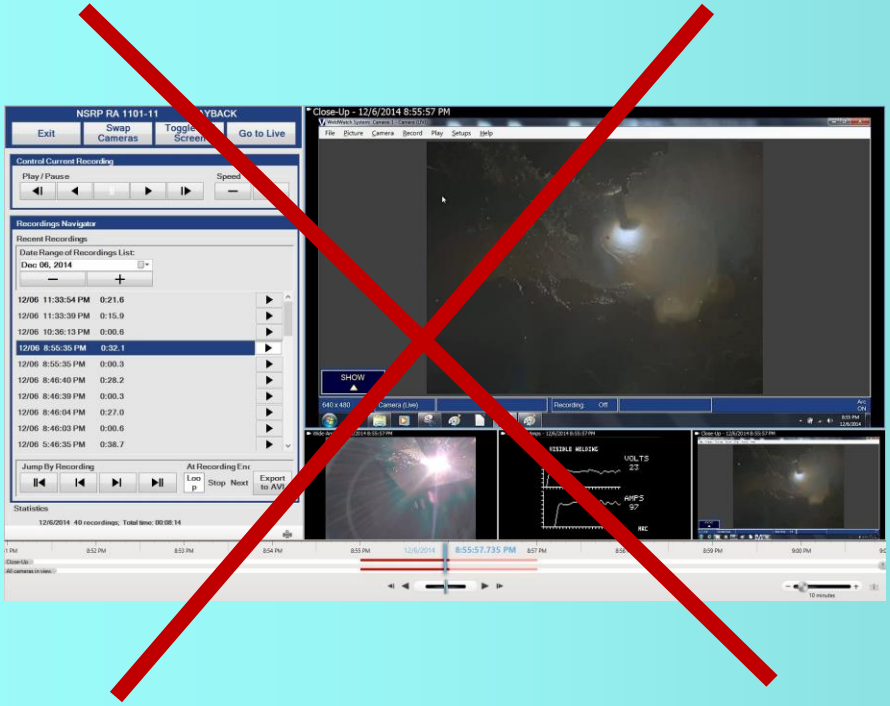
Replace network interface box with module mounted on back

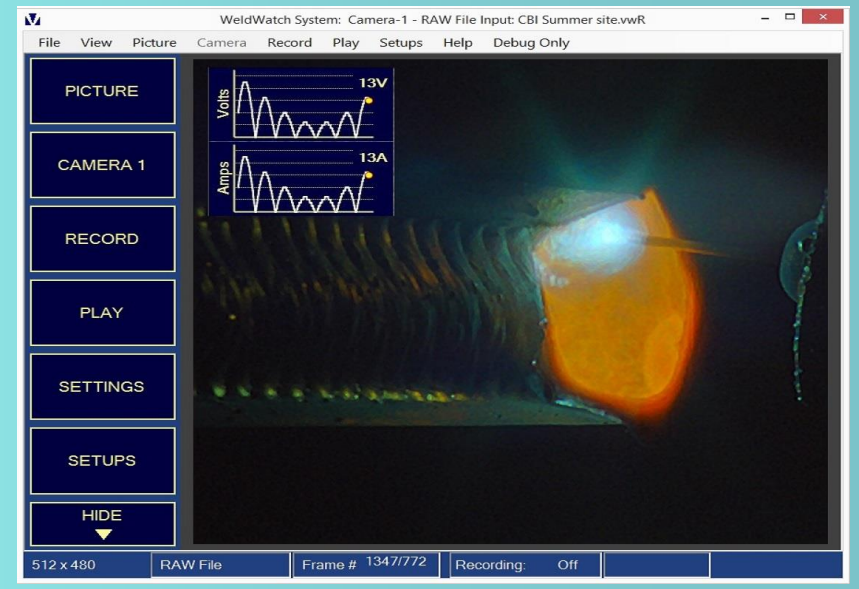
- Custom circuit for Volt-Amps (1 kHz samples)

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Simplify Screen and Controls





VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Training Tests at Bollinger

- 1 week intense test with 2 novice trainees

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Test Scenario

- Trainees used the video table freely along with traditional booth practice
- Instructors came by and gave advice intermittently, just as they would with booth-work
- Trainees used the station alone and together

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Tutoring Tests at Ingalls Shipyard

- Instructors spent 15 to 30 minutes **Coaching** the trainee until they ‘got’ the technique
- Trainees then practice back in their booth.

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Further Testing at Manchester With Big-Screen

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Manchester Lesson Testing

- Repeated Ingalls methods of 1-on-1 tutoring followed by student practice in their weld booth
- Expanded 1-on-1 tutoring to allow student to stay after lesson and practice up to 2 hours at video station
- Used video station as a testing/grading tool

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Bollinger Test Training Results

- Trainees advanced noticeably faster than an average trainee.
- Work in pairs was surprisingly effective and forced trainees to think critically about the weld process and technique.
- Both reached first level qualification in under a week – matching the best for trainees receiving traditional instruction.

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Results at Ingalls Shipyard

- Found that approx. 2/3 of trainees benefitted from the video tutoring
- 1/3 had no effect (no harm)

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Summary Lesson Results

- Big screen made demos much more effective
  - Instructors saved time normally spent repeating demos to reach all the trainees.
- 1-on-1 tutoring effective in short and long sessions
- Students practicing in pairs forced critical thinking in the ‘teaching’ student.
- Students working together was a welcome break from lonely weld practice
- Using video station as a testing tool did not work well. Students were nervous under the camera and dreaded the video sessions.

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Video is Not a Simulator

- We were surprised to find that most instructors derided simulators as a technology looking for a use
- They spoke of them expensive eye candy that is used for a day and then sits in the corner.

- We did not encounter this for the Video Tutor Station
- Instructors perceived video differently. They recognized it as a simple and useful tool.
- **Video is a tool of the instructor, not a replacement.**

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Tech Transfer.

Market Feedback at FabTech Chicago 2015

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM
NSRP

Tech Transferred

- First orders (complete EDU systems) shipped in April 2016 ($16k with educational discount)
  - UA 597 Pipefitters Training Ctr. (Mokena, IL)
  - Wallace State Comm. College (Hanceville ,AL)
  - Fox Valley Tech School (Appleton, WI)

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Videos to Document and Instruct Were Shot at Magnet School

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

10 Videos

1. Demo and Tutoring Station Overview
2. From the Instructor's Viewpoint
3. Quick Weld Recording Session
4. System Walk-through
5. Demo Training Session
6. Quick Tour of Software
7. Lesson Suggestions
8. Tutor Station Software and Settings
9. Tips for better videos
10. Advanced Features

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Videos Are Available

NSRP Site:

www.nsrp.org/videos-2013-450/

Visible Welding YouTube Channel

https://www.youtube.com/user/visiblewelding

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

VISIBLE WELDING

Looking Ahead

Visible Welding Cameras

Since 2005

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Welder Shortage will Persist

- US Navy wants to speed **WELDING**

- More Welders
- Faster Welders (more productive)
- Mechanization
- Automation

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Shipbuilding Welding Does Not Fit “Automation”

- Low Volume
- Many unique components and compartments
- Hard to reach welds

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Weld Automation has a Long-Standing Gap

Fully Manual Hand Welding	Mostly Manual Computer-in-Loop	Mostly Automatic Man-in-Loop	Fully Automatic Robot
	???		

VISIBLE WELDING

National Shipbuilding Research Program NSRP

Tele-Surgery In Use

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Robotic Surgical Setup

NOT a ROBOT – No Programming

- Surgeon watches 3D video
- Surgeon manipulates haptic controls
- Computer-controlled scalpel follows surgeon's hand
- Computer can remove hand-shake, slips and 'sneezes.'
- Can do 'tasks' like

  tie sutures

VISIBLE WELDING

Mechanization Can Help Welder Shortage

- Make welders more productive
- Faster time to mastery: Eliminate years required to gain muscle memory by substituting computer assist and guidance
- Expand into a new labor pool – young people with video-game skills.
  - OMG! Can “totally” train with simulators.

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Weld-by-Wire Servo System

- Weld-by-wire with a mechanical welding arm that follows the welder's hand motion.
- NO Programming; welder just drives.

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

3 Elements Required

- Mechanical welding arm to follow the welder's hand motion.
- Haptic controls allow welder to feel distance to seam, speed, walls, etc. in their fingertips.
- Advanced vision and instrumentation

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Farther Down the Road

- Computer assistance will get better
- Operation will become easier
- Before you know it, AI, Artificial Intelligence, Will Come.
  - If Google and Apple can make self-driving cars, they can make self-welding machines.

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

NEWSFLASH

Google Isn’t Working on Welding,

But Progress is Still Being Made

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

RTT Mechanized System Developing Haptic Control

- Welder steers weld head using Video feed

youtube.com/watch?v=OCpxhTP9UdA

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

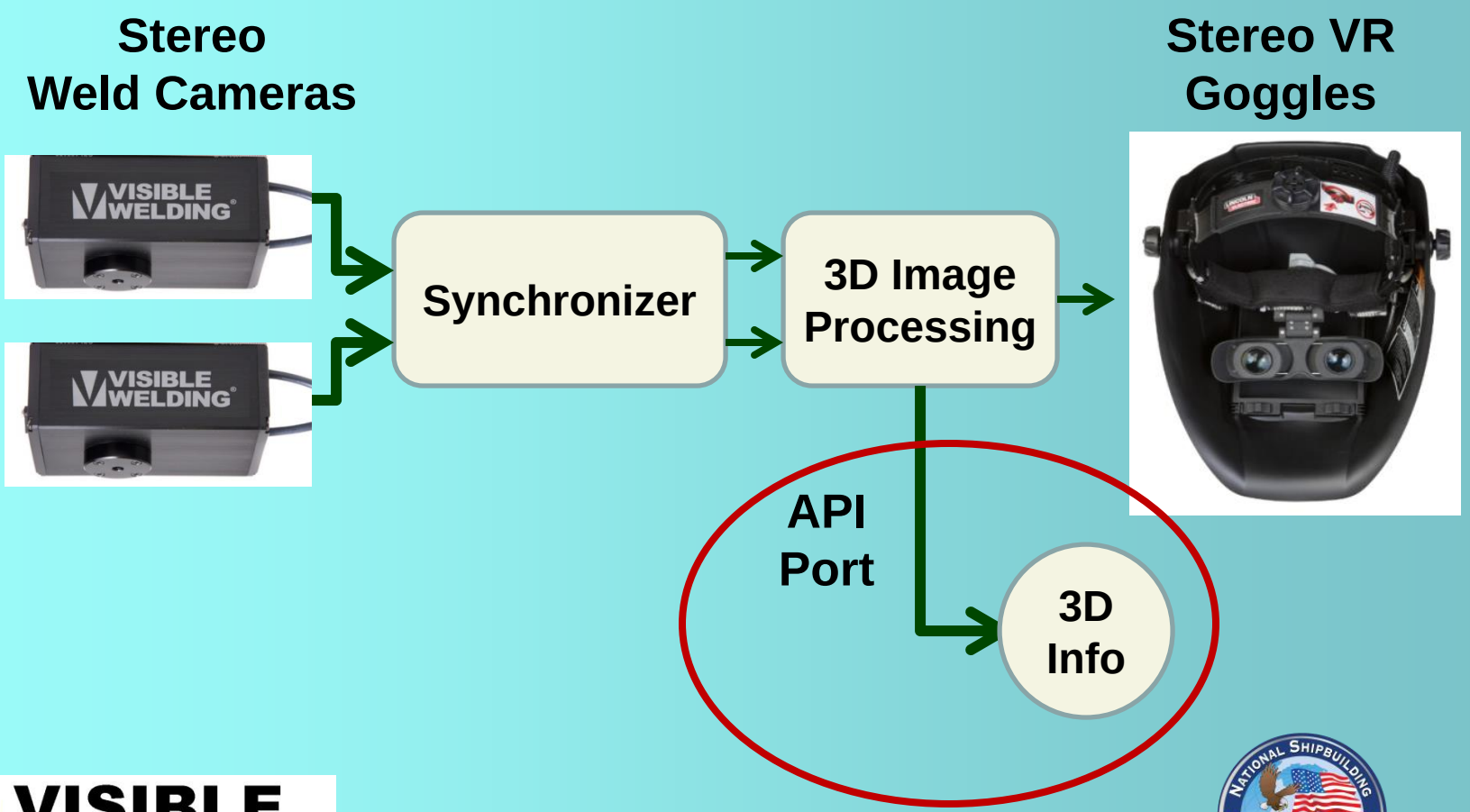
3D Mirror-Weld Project will Demonstrate 3D Steering

youtube.com/watch?v=yNdbHSaP5xQ

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Support Weld Research With Open 3D API



VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

VISIBLE WELDING

Multi-Spectral Sensor

NSWCCD IR Camera

Visible Welding Cameras

Since 2005

VISIBLE WELDING

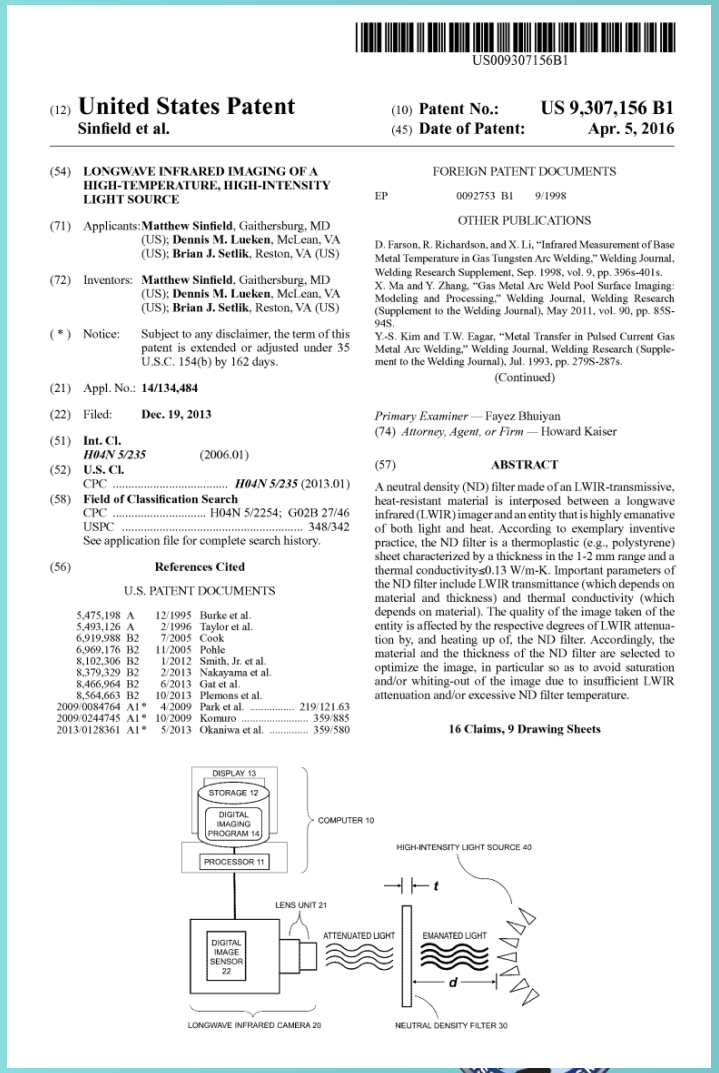
NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Tech Transfer of NSWCCD Patented Technology

LWIR Imaging of Welds

Invented by:

- Matthew Sinfield
- Dennis Lueken
- Brian Setlik



US009307156B1

(12) **United States Patent**
Sinfield et al.

(10) **Patent No.: US 9,307,156 B1**
(45) **Date of Patent: Apr. 5, 2016**

(54) **LONGWAVE INFRARED IMAGING OF A HIGH-TEMPERATURE, HIGH-INTENSITY LIGHT SOURCE**

(71) Applicants: **Matthew Sinfield**, Gaithersburg, MD (US); **Dennis M. Lueken**, McLean, VA (US); **Brian J. Setlik**, Reston, VA (US)

(72) Inventors: **Matthew Sinfield**, Gaithersburg, MD (US); **Dennis M. Lueken**, McLean, VA (US); **Brian J. Setlik**, Reston, VA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 162 days.

(21) Appl. No.: **14/134,484**

(22) Filed: **Dec. 19, 2013**

(51) **Int. Cl.**
H04N 5/235 (2006.01)

(52) **U.S. Cl.**
CPC ***H04N 5/235*** (2013.01)

(58) **Field of Classification Search**
CPC H04N 5/2254; G02B 27/46
USPC 348/342
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,475,198	A	12/1995	Burke et al.	
5,493,126	A	2/1996	Taylor et al.	
6,919,988	B2	7/2005	Cook	
6,969,176	B2	11/2005	Pohle	
8,102,306	B2	1/2012	Smith, Jr. et al.	
8,379,329	B2	2/2013	Nakayama et al.	
8,466,964	B2	6/2013	Gat et al.	
8,564,663	B2	10/2013	Plemons et al.	
2009/0084764	A1 *	4/2009	Park et al.	219/121.63
2009/0244745	A1 *	10/2009	Komuro	359/885
2013/0128361	A1 *	5/2013	Okaniwa et al.	359/580

FOREIGN PATENT DOCUMENTS

EP	0092753 B1	9/1998

OTHER PUBLICATIONS

D. Farson, R. Richardson, and X. Li, "Infrared Measurement of Base Metal Temperature in Gas Tungsten Arc Welding," Welding Journal, Welding Research Supplement, Sep. 1998, vol. 9, pp. 396s-401s.
X. Ma and Y. Zhang, "Gas Metal Arc Weld Pool Surface Imaging: Modeling and Processing," Welding Journal, Welding Research (Supplement to the Welding Journal), May 2011, vol. 90, pp. 85S-94S.
Y.-S. Kim and T.W. Eagar, "Metal Transfer in Pulsed Current Gas Metal Arc Welding," Welding Journal, Welding Research (Supplement to the Welding Journal), Jul. 1993, pp. 279S-287s.
(Continued)

Primary Examiner — Fayez Bhuiyan
(74) *Attorney, Agent, or Firm* — Howard Kaiser

(57) **ABSTRACT**

A neutral density (ND) filter made of an LWIR-transmissive, heat-resistant material is interposed between a longwave infrared (LWIR) imager and an entity that is highly emanative of both light and heat. According to exemplary inventive practice, the ND filter is a thermoplastic (e.g., polystyrene) sheet characterized by a thickness in the 1-2 mm range and a thermal conductivity≤0.13 W/m-K. Important parameters of the ND filter include LWIR transmittance (which depends on material and thickness) and thermal conductivity (which depends on material). The quality of the image taken of the entity is affected by the respective degrees of LWIR attenuation by, and heating up of, the ND filter. Accordingly, the material and the thickness of the ND filter are selected to optimize the image, in particular so as to avoid saturation and/or whiting-out of the image due to insufficient LWIR attenuation and/or excessive ND filter temperature.

16 Claims, 9 Drawing Sheets

VISIBLE WELDING

Visible v. Long-Wave Infra-Red

- LWIR Sees through smoke and spatter
- Great view of the puddle edges / size.

youtube.com/watch?v=gHFZD1l_7Bs

youtube.com/watch?v=R54pQizDUCI

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

CRDA
Visible Welding and NSWCCD

- NSWCCD is refining the materials

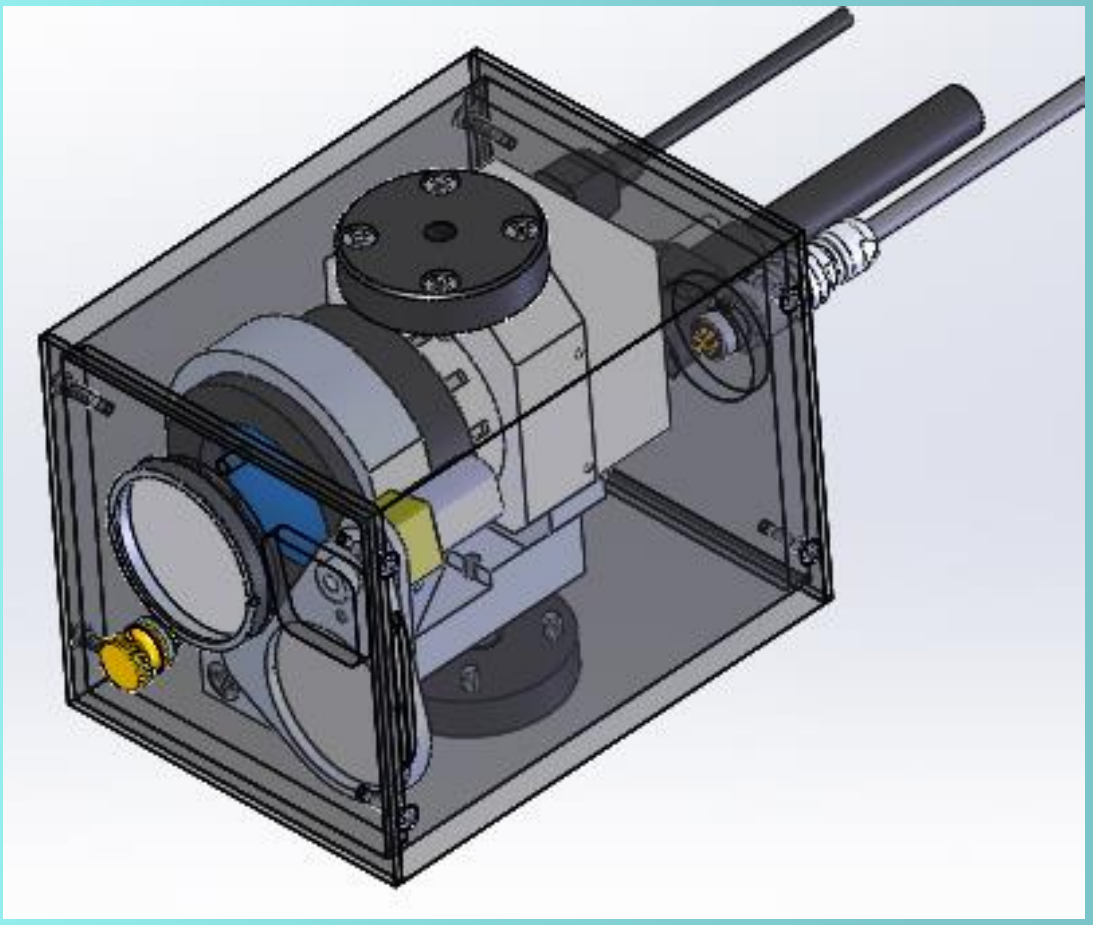
- Visible creating a commercial package
  - Rugged Camera case
  - Imaging processing software
  - User GUI
  - Record and playback
  - Distribution and Support

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Intertest Created the Case

- Rugged
- Close Focus
- Auto IR Filter



VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

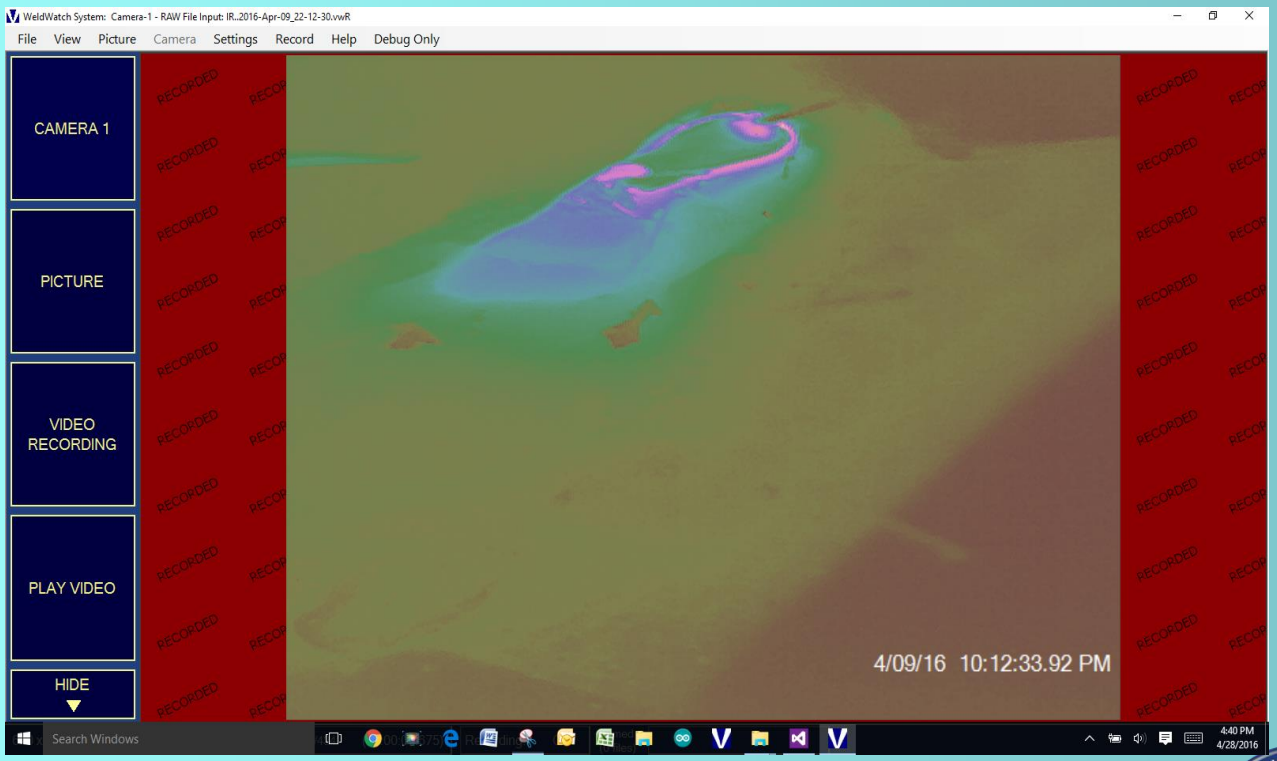
Live Demo on Today's Tour

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Ported to Run Under WeldWatch

Inherit WeldWatch Image Processing, recording and other functions



VISIBLE WELDING

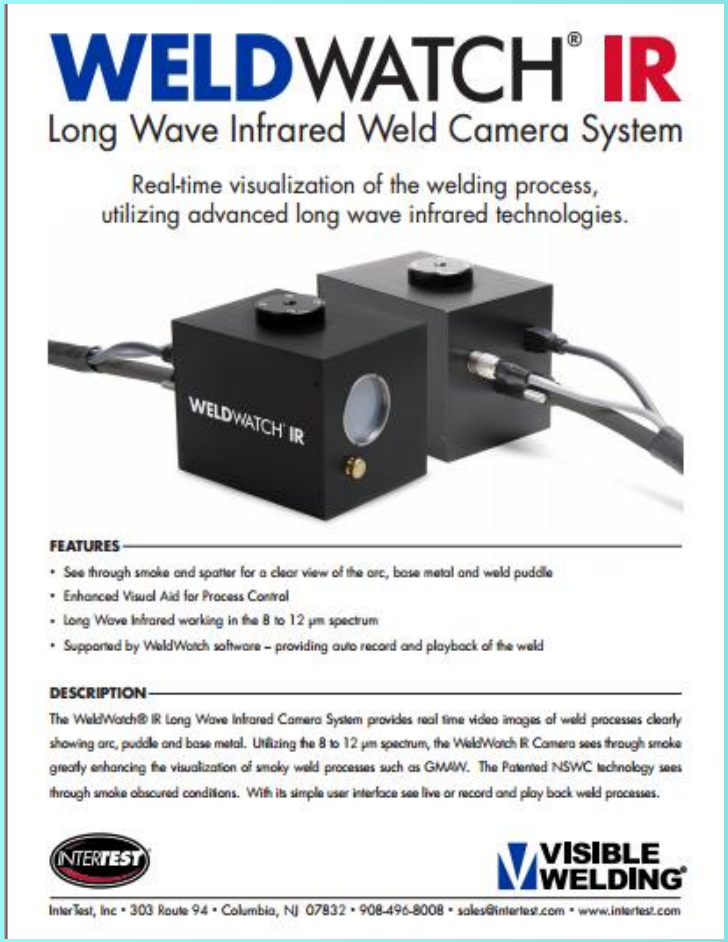
NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Including VAmpWatch

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP

Available Q3, < $20k



WELDWATCH® IR

Long Wave Infrared Weld Camera System

Real-time visualization of the welding process, utilizing advanced long wave infrared technologies.

FEATURES

- See through smoke and spatter for a clear view of the arc, base metal and weld puddle
- Enhanced Visual Aid for Process Control
- Long Wave Infrared working in the 8 to 12 µm spectrum
- Supported by WeldWatch software – providing auto record and playback of the weld

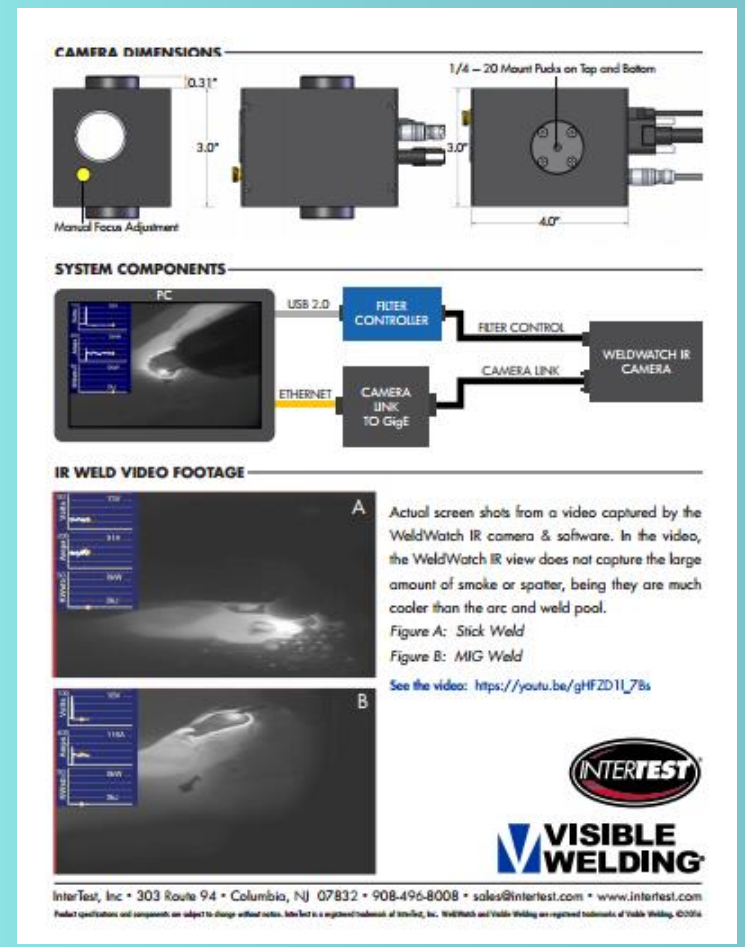
DESCRIPTION

The WeldWatch® IR Long Wave Infrared Camera System provides real time video images of weld processes clearly showing arc, puddle and base metal. Utilizing the 8 to 12 µm spectrum, the WeldWatch IR Camera sees through smoke greatly enhancing the visualization of smoky weld processes such as GMAW. The Patented NSWC technology sees through smoke obscured conditions. With its simple user interface see live or record and play back weld processes.

INTERTEST

VISIBLE WELDING

InterTest, Inc • 303 Route 94 • Columbia, NJ 07832 • 908-496-8008 • sales@intertest.com • www.intertest.com



CAMERA DIMENSIONS

SYSTEM COMPONENTS

IR WELD VIDEO FOOTAGE

Actual screen shots from a video captured by the WeldWatch IR camera & software. In the video, the WeldWatch IR view does not capture the large amount of smoke or spatter, being they are much cooler than the arc and weld pool.

Figure A: Stick Weld

Figure B: MIG Weld

See the video: https://youtu.be/gHFZD1l_78s

INTERTEST

VISIBLE WELDING

InterTest, Inc • 303 Route 94 • Columbia, NJ 07832 • 908-496-8008 • sales@intertest.com • www.intertest.com

VISIBLE WELDING

National Shipbuilding Research Program NSRP

VISIBLE WELDING

Cue the Balloons

Visible Welding Cameras

Since 2005

VISIBLE WELDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM NSRP