Towards Wound Closure Optimization: Final Report

Larry I. Sanders

LaserSurge, Inc.

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Office of Naval Research

Department of the Navy
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Extensive experimentation with many combinations of lasers and chromophores was conducted to determine the optimal parameters for laser tissue welding. New Zealand White rabbit small bowel was used as an in vitro model for this study. The analysis indicates that particular chromophores can be utilized to enhance the effectiveness of certain lasers. For example, India ink is an effective chromophore for the 1.06 micron Nd:YAG laser, while blood is most effective for the 0.514 micron Ar laser. The 2.1 micron Ho:YAG laser produced strong chromophore-free welds, and also produced strong welds in the presence of India ink and blood. The laser welding literature indicates that Indocyanine Green is an adjuvant to laser welding with the 0.808 micron Ga:Al:As diode laser. The diode lasers that were examined in this study did not provide sufficient energy to weld tissue and evaluate these statements. Indocyanine Green did prove to be an effective chromophore for the 0.532 micron KTP laser. The apparatus designed and developed for this study provides an unique method to determine the laser tissue welding parameters which will produce the strongest welds.
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Summary

Extensive experimentation with many combinations of lasers and chromophores was conducted to determine the optimal parameters for laser tissue welding. New Zealand White rabbit small bowel was used as an in vitro model for this study. The analysis indicates that particular chromophores can be utilized to enhance the effectiveness of certain lasers. For example, India ink is an effective chromophore for the 1.06 micron Nd:YAG laser, while blod is most effective for the 0.514 micron Ar⁺ laser. The 2.1 micron Ho:YAG laser produced strong chromophore-free welds, and also produced strong welds in the presence of India ink and blood. The laser welding literature indicates that Indocyanine Green is an adjuvant to laser welding with the 0.808 micron Ga:Al:As diode laser. The diode lasers that were examined in this study did not provide sufficient energy to weld tissue and evaluate these statements. Indocyanine Green did prove to be an effective chromophore for the 0.532 micron KTP laser. The apparatus designed and developed for this study provides an unique method to determine the laser tissue welding parameters which will produce the strongest welds.

Introduction

LaserSurge, Inc., of Rochester, NY was established to develop, demonstrate, and facilitate the clinical use of automated surgical laser delivery systems. The speed, effectiveness, and reliability of using laser energy to connect or weld living tissue makes laser tissue welding one of the most promising areas of medical research today. The controlled application of laser energy thermally induces intrinsic tissue changes which lead to both immediately strong bonds between tissue and rapid restoration of tissue function. Conventional surgical techniques typically require sutures and staples to close tissue wounds or to construct anastomoses (i.e., surgical connections that provide functional communication between hollow organs such as bowel). A surgeon's bonding of tissue using laser tissue welding can be compared to a metal worker's handling of steel. Whereas the conventional suturing or stapling is like the use of screws or rivets in steel, laser tissue welding, like welding steel, uses an outside energy source to cause intrinsic material changes which alone provide for the strong bond. A fundamental requirement to weld either material is that the surfaces to be welded be in intimate contact with each other. To fully realize the enormous potential of this revolutionary wound closure modality, an enhanced theoretical understanding of laser tissue welding is essential. In an effort to better recognize and evaluate the many factors that determine a successful laser tissue weld, LaserSurge has developed a laser tissue welding equation which describes laser tissue welding as a function of its component parameters: lasing parameters, chromophores, and tissue parameters. Using this structured approach, an investigator can readily dissect and compare the effects of changes in individual or multiple variables. This study was designed to identify the most favorable laser tissue welding conditions. To accomplish this goal, an integrated laser tissue welding and tensiometry (weld strength measurement) system was designed, constructed, and tested. This system permits the user to selectively vary several parameters of interest including welding temperature, welding time, aperture size, laser type, power, and chromophores. Experimental trials using different combinations of the aforementioned parameters were performed in this study.
Methods, Assumptions, and Procedures

Methods

Device Refinement and Evaluation

In order to examine the effects of multiple combinations of lasers and chromophores, a new device was developed to quantify the strength of laser welds. The laser welding/tensiometry apparatus permits any laser which can be transmitted through an optical fiber to be coupled to the beam alignment system. The beam alignment system configured the beam so that it slightly overfilled the aperture. The beam passed through a high-speed shutter, which opened and closed in response to the thermocouple temperature reading. The aperture size was fixed at either 0.5 x 4.0 mm or 2.0 x 4.0 mm, and the aperture was placed just above the surface of the tissue strips to be welded. The beam impinged perpendicularly upon the tissue strips at the site of apposition. A thermocouple was placed between the strips so that it was positioned 1 mm beneath the surface of the weld. The strips were then brought into contact by a piezoelectric motor under computer control. The laser welding temperature control program allowed the operator to designate the parameters of interest, including the welding control temperature. Following welding, the welded tissue was pulled apart and the load required to rupture the weld was measured as a function of the distance moved. Graphs of load versus distance were generated to determine maximum weld strength.

The tensiometry software was seamlessly integrated into the laser welding control program by Mr. Williar Kraft. This new program eliminated the need to reboot the computer between experimental trials. This major improvement permitted more rapid data acquisition and reduced the average time between trials to approximately five minutes.

The thermocouple placement system has also been modified to provide more reproducible and accurate temperature measurements. A single thermocouple was mounted on a specially-designed plexiglas holder. This thermocouple was placed 1 mm below the surface of the apposed tissue at the site of welding, as depicted in Figure 1 in Appendix C. The temperature recorded from the thermocouple controlled the opening and closing of the shutter mechanism, thereby maintaining the designated tissue welding temperature. The new thermocouple holder permits easier, faster, and more reliable thermocouple placement.

A new problem surfaced during the experimentation. The stages began to stall and resist free movement because of dried bowel and saline which had entered the stage. The stages were removed, cleaned, and remounted. Periodic cleaning and maintenance have rectified this problem.

Assumptions

An implicit assumption in the original design of this experimental protocol is that the freshly harvested in vitro bowel very closely resembles native in vivo bowel. The time from resection to welding was minimized by sequentially harvesting small sections of bowel from intravenously anesthetized rabbits. The resected bowel was placed in physiological saline to maintain its integrity, while the remaining intact bowel was returned to the
abdomen for later use. Tissue processing and handling were minimized to the extent possible. Tissue trauma was minimized by handling and manipulating the bowel gently. We have assumed that the in vitro tissue would not be significantly altered by the removal and processing steps. The veracity of this assumption is important since the intent of this study is to generate data which will be readily transferrable to clinical applications.

One set of experiments suggests that the in vivo bowel model may not be wholly representative of the in vivo state. When more than one hour elapsed between bowel resection and welding, the welds produced were clearly inferior to welds produced using freshly harvested bowel under the same conditions. This lack of success may be attributable to changes in tissue turgidity and perhaps also to other biological effects (platelet aggregation and adhesion, etc.). The bowel turgidity appears to change as a result of storage in physiological saline. It is unclear whether this change might influence the laser welding of bowel. Ischemia and oxygen deprivation may also cause changes which are responsible for the difference seen between welding in vitro and in vivo.

As a consequence of the in vitro alterations to bowel, the weld strengths obtained in this study were much lower than anticipated based upon our earlier in vivo data. In order to obtain recognizable welds, the highest laser power and temperature settings were employed. Several of the lasers, namely the diode and Argon++, were unable to provide the high power output required to weld tissue. Thus, the results for the diode and Argon lasers are inconclusive, and few or no welds were performed using these lasers.

**Experimental Procedure**

The experimental protocol required the resection of small bowel from New Zealand White rabbits. As discussed in the third quarter 1990 report, weld strength appears to diminish as the length of time between bowel harvesting and welding increases. In order to more closely emulate the clinical setting, fresh bowel was sequentially resected from an intravenously anesthetized rabbit (see Figure 2 in Appendix C for a complete description of the experimental protocol). The harvested tissue was cut into strips measuring 4 mm x 20 mm. The strips were carefully positioned on the laser welding/tensiometry apparatus. The thermocouple was positioned 1 mm deep at the site to be welded and the tissue strips were brought into apposition. Next, the laser was fired and, following the laser exposure, a welded tissue seam was created where the tissue strips were in contact. Thus, the thermocouple was imbedded in the welded tissue. The laser welding temperature control software directed the opening and closing of the shutter to maintain the designated welding temperature. Immediately following laser welding, the tissue was pulled apart and the load required to break the bond (in grams) was measured as a function of the distance (in millimeters) moved. Load versus distance plots were generated to assess the strength of each weld. Maximum strength was determined for each weld.

The 0.808 micron diode lasers used in this study were not powerful enough to use for laser welding using the apparatus as designed. Both LaserSurge's Spectra Diode Laboratory 3 W laser diode array and Columbia-Presbyterian's 1.5 W IRIS Medical OcuLight SL diode were coupled to the laser welding/tensiometry apparatus. The power delivered to the weld site, as measured by a power meter, was insufficient to weld tissue, since less than 0.15 W was transmitted through the optical delivery system. No appreciable temperature rise was observed, even with the Indocyanine Green chromophore. Thus, further studies of the diode laser and its interaction with chromophores were not performed.
Another laser which was initially included in this study was the 1.32 micron Nd:YAG. Rochester General Hospital has one 1.32 micron laser, and it had not been used in more than one year. When the laser was turned on, the laser’s power setting mechanism did not function. This laser was unable to be repaired prior to the conclusion of this study. Thus, the 1.32 micron Nd:YAG laser was not studied further.

The Rochester General Hospital 0.514 micron Ar laser was studied. This laser, a 7.5 W Lexel Aurora Mode 150 Pump Laser and a Model 600 Dye Laser, is a tremendously large research unit. The delivered power was quite low, approximately 0.7 W, and this precluded testing of some chromophore and temperature combinations.

The 100 W, CW, Sharplan 2100 1.06 micron Nd:YAG laser was examined using all chromophores and both aperture sizes. The maximum power of 5.0 W (delivered to the site of welding) was selected for use throughout since, at the lower temperatures even with this high power, weld strength was low. Thus, the lower power settings were not examined.

The Columbia-Presbyterian Medical Center in New York, NY has a Coherent Two Point One Holmium laser, with a maximum output power of 15 W operating in pulsed mode. The 2.1 micron Ho:YAG was examined at approximately 1 and 5 W with the small and large apertures.

The 20 W, CW, LaserScope 0.532 KTP laser was also examined in this study. Both aperture sizes were examined at the highest obtainable delivered power of 4 W.

The power delivered to the weld site through the optical system was occasionally not sufficient to attain some of the higher temperatures. These results are indicated in the data section that follows.

Results and Discussion

Results

The data collected and included in the subsequent analysis are limited in number. Most of the early data collected using the ASYSTANT data acquisition program has been excluded due to problems with the tensiometry apparatus, as will be explained in the Discussion (see Appendix B for these force versus distance plots). A great deal of time was devoted to software development and testing, and therefore, the results reported herein generally come from one or two samples. A thorough statistical analysis was not performed; rather, averages were obtained for each laser and chromophore combination. These averages were assessed to determine the most promising combinations. The averages are presented in Table 1.
### TABLE 1- MAXIMUM WELD STRENGTH (g)

#### 0.514 Micron Argon (Small Aperture, 0.7-0.8W delivered)

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#### 0.532 Micron KTP (Small Aperture, 4.0 W delivered)

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#### 0.532 Micron KTP (Large Aperture, 4.0 W delivered)

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#### 1.06 Micron Nd:YAG (Small Aperture, 5.0 W delivered)

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<th>NO CHROMO</th>
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</thead>
<tbody>
<tr>
<td>UNWELDED</td>
<td>1.0</td>
<td>0.3</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>50º C</td>
<td>6.7</td>
<td>2.7</td>
<td>1.3</td>
<td>1.5</td>
</tr>
<tr>
<td>60º C</td>
<td>6.1</td>
<td>6.8</td>
<td>0.9</td>
<td>-</td>
</tr>
<tr>
<td>70º C</td>
<td>5.5</td>
<td>24.5</td>
<td>2.0</td>
<td>4.4</td>
</tr>
<tr>
<td>80º C</td>
<td>4.9</td>
<td>4.1</td>
<td>0.8</td>
<td>1.4</td>
</tr>
<tr>
<td>100º C</td>
<td>11.3</td>
<td>5.3</td>
<td>3.1</td>
<td>4.1</td>
</tr>
</tbody>
</table>

NOTES:
BLOOD = fresh whole blood collected in a Vacutainer blood collection tube with heparin.
ICG = prepared as a 2X solution (25 mg Indocyanine Green per 10 ml aqueous solvent).
- = unable to perform.
Discussion

Thermocouple Placement

The earlier observation that thermocouple placement is crucial continued to be supported by experimentation. If the thermocouple is placed above the weld site, the recorded temperature is an artefact which corresponds to the heating of the thermocouple and not to the heating of the tissue at the weld site. If the thermocouple is placed too deeply, it again fails to accurately represent the temperature increase at the site of welding since the recorded temperatures are lower than those at the weld. Since the laser welding temperature control program controls the temperature at the weld site based upon the thermocouple measurements, proper thermocouple placement is imperative. The final thermocouple holder design provides adequate reproducibility. When thermocouple placement was incorrect, as evidenced by either an abnormally short or a protracted time to attain the stipulated control temperature, the trial was repeated with fresh tissue strips.

Prior to the design and construction of the new thermocouple holder, there were major problems with thermocouple placement. The thermocouple was difficult to position reproducibly, and thus, much of the early data is erroneous. Since the temperature control program utilizes feedback from the thermocouple, and since the thermocouple was incorrectly positioned, the time of laser exposure as well as the actual temperature at the weld site were incorrect as well.

Chromophore Delivery and Placement

Precise chromophore placement was another important factor in this study. Each of the chromophores tested was a liquid. Attempts were made to deposit the chromophore at the weld site using a micropipettor. This allowed a fixed amount of chromophore to be deposited, but the application was not evenly distributed along the weld seam. A cotton-tipped applicator was used to apply a barely visible coat of chromophore to both tissue strips prior to bringing the strips into apposition. The strips were then brought into contact by the computer-controlled piezoelectric motor. When the requisite apposition was obtained, the top surface of the weld site was gently wiped with a clean cotton-tipped applicator to remove any chromophore which oozed upwards when the tissue was compressed. When too much chromophore was placed at the top of the weld site, excessive energy was absorbed at the surface, rather than in the deeper areas of the weld site, and smoking, charring, and diminished weld strength were noted. Chromophore placement in the deeper half of the weld site resulted in stronger, more homogeneous welds.

Maintenance of equipment, software package, and its effect on data.

Maintenance of the laser welding/tensiometry apparatus was crucial. The stages upon which the tissue is clamped are highly susceptible to stalling if they become contaminated with dried bowel and saline. Stalling of the motor due to a contaminated stage was readily apparent on the first control run of the day, as the tensiometry plots of force versus distance indicated the resistance of the stage to movement. Periodic removal of the stages for cleaning and maintenance was a necessity. The outside surfaces of the laser welding/tensiometry apparatus were carefully cleaned after each use. These steps prevented corrosion of the apparatus.
Initially, however, the problem of stalling was not so readily apparent. Using the original ASYSTANT data acquisition software package, we were unable to obtain plots of the data in either real time or immediately after the completion of the trial. To plot data in ASYSTANT required a lengthy process of file conversion and computer rebooting. Thus, data was not analyzed until after the animal had been sacrificed. This software problem resulted in the generation of tremendous amounts of erroneous data (see Appendix B), since it was impossible to interpret the effect of stage resistance on the measured weld strengths.

Since there were substantial problems with the software, several different software programs were utilized during this study. ASYSTANT was utilized for the earliest data acquisition, but it was cumbersome and inefficient. The time between welding and tensiometry was often more than five minutes. The final version of the temperature control and tensiometry program is written in BASIC and can switch from the welding temperature control program to tensiometry in a matter of seconds. The data acquired using the BASIC programs was imported into either Lotus 1-2-3 version 2.1 or Lotus Symphony release 2.0 for subsequent analysis and graphing.

All data were collected at the laboratory and were stored on 3.5 inch high density floppy disks to permit data analysis at the office. Additional backup copies of the data have been made for the LaserSurge software archives in case of loss or damage to the working disks. These disks are stored off site.

Overall results- difference in aperture size and its effect, power delivered and its effect, chromophores and their effect, time of welding and its effect

Aperture size was one parameter examined in this study. Two aperture size were utilized, 0.5 x 4.0 mm and 2.0 x 4.0 mm. The small aperture, with its attendant higher power density, generally produced stronger welds. This was true for all lasers examined, except for the Ho:YAG. For the 5.0 W Ho:YAG trials, the large aperture produced better welds with either Indocyanine Green or in the absence of chromophore. For the 1.5 W trials, the large aperture again produced stronger welds with Indocyanine Green, blood, and without a chromophore.

Power densities can also be calculated for the two aperture sizes used. The power densities, in W/cm², were:

- Small Aperture, 1 W- 50
- Small Aperture, 5 W- 250
- Large Aperture, 1 W- 12.5
- Large Aperture, 5 W- 62.5.

Since the large aperture appeared to weld better than the small aperture for the Ho:YAG laser, perhaps the increased surface area of welding was responsible for the strong welds seen.

High and low power settings were also examined. The higher power of 5 W produced welds of superior strength when compared to the lower power welds. This is true for equal welding temperatures, and seems surprising since the lower power setting often required a longer total laser exposure to reach the desired welding temperature.
The effect of the length of exposure to laser energy on weld strength was not assessed in this study. Most of the temperature settings used required between 15 and 30 seconds to reach the designated control temperature. When the control temperature was attained, feedback from the thermocouple to the shutter control maintained the desired temperature for 10 s. Since there was significant variation in the amount of time required to reach the predetermined welding temperature, the differences due to the variation of controlled exposure would be very difficult to interpret. Thus, a single, fixed 10 s exposure was consistently used throughout the study.

The relationship between maximum temperature and weld strength is also unclear. The highest temperature examined, 100 degrees C, usually elicited smoking as well as tissue blanching and desiccation. Occasional charring was noted in some samples. As mentioned above, the time required to reach the desired temperature varied from sample to sample. Thus, the conclusion that weld strength appears to increase with increasing temperature must be tempered with caution. This is particularly true because the 100 degree welds were often slightly weaker than the 80 degree welds. We speculate that this might be due to increased thermal injury at the higher temperature. Many samples that were welded at 100 degrees became charred or carbonized, and the tissue was dry and brittle. This type of extreme thermal injury may compromise the strength of the weld, and may explain why the 100 degree welds were weaker than the 80 degree welds. Many of the 100 degree welds that were mildly desiccated and blanched seemed to be strongly welded. The overall pattern seemed to indicate that weld strength did increase with increasing temperature.

Conclusions

Laser tissue welding is successful when the correct combinations of laser wavelength, chromophore, and aperture size are utilized. Based upon the in vitro results obtained in this study, the following laser/chromophore combinations appear to show promise for laser tissue welding:

- 0.514 micron Ar**- blood or ICG chromophore
- 0.532 micron KTP- blood or ICG chromophore
- 1.06 micron Nd:YAG- India ink chromophore
- 2.1 micron Ho:YAG- blood, India ink, or no chromophore.

In comparing the weld strength produced by each of these lasers, the Ho:YAG laser clearly produced the strongest welds. Many of the Ho:YAG welds appeared to be full thickness welds. The optimal welding temperature for any of the tested laser and chromophore combinations appeared to be between 80 and 100 degrees C. The higher power levels seemed to produce stronger welds, at least in the range of 1 to 5 W. A certain minimum power is required to increase the tissue temperature to the desired range (80 to 100 degrees C). Whether additional power above this threshold actually improves the strength of the welds cannot be asserted from the data collected.
The laser welding/tensiometry apparatus developed for this study provides an unique and ideal method to analyze the effects of various parameters on weld strength. The in vitro model has some limitations, and an in vivo corroboration of these results is needed. An in vivo model would permit an assessment of the effects of thermal injury and healing, two clinically relevant issues.

Laser tissue welding continues to show great promise for clinical application, and the data generated in this study provide a solid foundation for future pre-clinical and clinical investigations of this new modality.
Appendix A- Included Data
small aperture
small aperture

INDIA INK-CONTROLLED AT 70°C
Small aperture  INDIA INK CONTROLLED AT 80°C
Small aperture  INDIA INK CONTROLLED AT 100°C
Small aperture BLOOD UNWELDED CONTROL

-37.1
-37.2
-37.3
-37.4
-37.5
-37.6
-37.7
-37.8
-37.9
-38.0
-38.1

SEP 270
Small aperture

BLOOD CONTROLLED AT 50°
(touched table at end of run)
BLOOD CONTROLLED AT 60°C
Small aperture  BLOOD CONTROLLED AT 70°C
BLOOD CONTROLLED AT 800
small aperture  BLOOD CONTROLLED AT 100°C
Small aperture    BLOOD CONTROLLED AT 100°C
Small aperture       BLOOD CONTROLLED AT 100°C
1.06mm Nd:YAG
Small aperture

ONE STRIP
REG UNWELDED CONTROL
106μm Nd:YAG
Small aperture

TWO STRIPS ICG - UNWELDED CONTROL

SEP 28 L
.06 μm Nd: YAG
Small aperture

ICG Controlled at 50°C
106 µm Nd: YAG
Small aperture

ICG Controlled at 585-600°C

SEP 28
106\mu m Nd:YAG
Small aperture
ICG CONTROLLED AT 70\degree C

SEP 28 0
0.6 μm Nd:YAG
Small aperture
ICG CONTROLLED AT 80°C
106μm Nd:YAG - Small aperture

ICG CONTROLLED AT 1050°C
6um Nd:YAG
Small aperture

INDIA INK CONTROLLED AT 80C

-29.6
-29.8
-30
-30.2
-30.4
-30.6
-30.8
-31
-31.2
-31.4
-31.6
-31.8
-32
-32.2
-32.4
0.6 μm Nd:YAG
Small aperture

ONE STRIP CONTROL

SEP 28
OCT 9, 1990

KTP laser $\rightarrow$ 20W out of laser $\rightarrow$ 4.0W delivered small aperture

$\text{Ferronyl} - \frac{1g \text{ Ferronyl}}{3\text{ml} 0.9\% \text{ saline}}$

$\text{Ferronyl} + \text{Blood} - \frac{1g \text{ Ferronyl}}{3\text{ml} \text{ whole blood in EDTA}}$
KTP - one step unwelded control

small aperture
KTP - two strip unwelded control

small aperture
kTP - two slip India ink
unwelded control
small aperture
KTP - India cellulose - 50°C

small aperture
KTP - India link - 600°C

small aperture
KIP - India ink - 70°C
small aperture
KTP - India hard - 80°C

Tc too superficial?

Small aperture
OCT6H

KTP - India ink - 80°C

small aperture
kTP - India ink - 100°C

Small aperture
KTP - India run - 100°C

small aperture
K1P - one step control

small aperture
OCT9S

KTP - two strip control
small aperture
KTP - two strip unwelded blood control
small aperture
KTP - Blood - 50°C

small aperture
KTP - Blood -60°C
small aperture
KTP - Blood - 70°C
small aperture
KTP - GET Blood - 100°C
small aperture
KTP - one strip unwelded control
small aperture
OCT1OB

KTP - two strip unwelded control
small aperture
KTP - 2 x ICG unwelded control
small aperture
KTP 2x ICC 50°C
small aperture
KTP - 2x ICG - 60°C

Small aperture
OCT10F1

KT - 2 x 1GHz - 70°C

Small aperture
KTP - 2x 1G - 80°C

small aperture
KTP - 2x 1CG - 100°C

Small aperture
KTP - one strip unwelded control

small aperture
kip - two strip unwelded control

small aperture
All trials for OCT 15, 1990

An hv Laser

Settings: Current Control

38A, 5.8W

0.7W delivered
Small Aperture
OCT15D

INDIA INK - 50 DEGREES
OCT15G1

INDIA INH - 70 DEGREES (64 DEGREES)
OCT 1591
BLOOD - 100 DEGREES (77 DEGREES)
OCT15M1

PLATO - 70 DEGREES (62 DEGREES)
OCT15P1

BLOOD: 100 DEGREES (56 DEGREES)
All trials for OCT 16, 1990
Av++ Laser
Settings: Current Control
38A, 58W
0.8W delivered
Small Aperture
OCT16F

2X IGG - 60 DEGREES (53 DEGREES)
For all trials on Oct 19, 1990

Ar++ Laser

Settings: Current control
32A, 60W

0.8W delivered
Small aperture
OCT19C

TWO STRIP UNWELDED BLOOD CONTROL
For all trials on Oct 24, 1996

Art Laser

Settings: Current Control
38A, 5.6W

0.7 Wlas lied
Small Aperture
OCT24B
TWO STRIP UNWELDED CONTROL
NOV8D- INDIA INK CONTROLLED AT 50

1.06 Nd + AG SMALL APERTURE
HOVBE - INDIA INK CONTROLLED AT 60
1.06 Nd IAG, SMALL APERTURE
NOV8F-INDIA INK CONTROLLED AT 70

106 H/172 SMALL APERTURE
NOVBC-INDIA INK CONTROLLED AT 80
1 OF DH XAC, SMALL APERTURE
DEC17A—ONE STRIP UNWELDED CONTROL

2.1 Hm:YAG, 1.0 W, SMALL APERTURE
DEC17B—TWO STRIP UNWELDED CONTROL

2.1 Hm:YAG, 1.0 W SMALL APERTURE
DEC17E—INDIA INK CONTROLLED AT 100

2.1 Hm YAG, 1.0 W SMALL APERTURE
DEC17F – NO CHROMO SET=100, TC MAX=70

2.1 Hz:YAG, 1.0 W, SMALL APERTURE

-0.00913795 6.9810344 1.949138 2.918104 -3.888793 -4.861207 -5.83319 -6.805173
DECI7H—INDIA INK CONTROLLED AT 60, 10 s
2.1 Hm:YAG, 1.0 W, SMALL APERTURE
DEC171—INDIA INK CONTROLLED AT 70, 10 s

2.1 Hm:YAG, 1.0 W, SMALL APERTURE
DEC17J—INDIA INK CONTROLLED AT 80, 10 s

2.1 Hm:YAG, 1.0 W, SMALL APERTURE
DEC17K—INDIA INK CONTROLLED AT 100, 10s
2.1 Hz:YAG, 1.0 W, SMALL APERTURE
DEC17M—NO CHROMO, CONTROLLED AT 50, 10s

2.1 Hm: YAG, 1.0 W, SMALL APERTURE
DEC170—NO CHROMO CONTROLLED AT 70, 10°

2.1 Hm: YAG, 1.0 W, SMALL APERTURE
DEC17P-NO CHROMO CONTROLLED AT 80, 10 s

21 Hm:YAG, 1.0 W, SMALL APERTURE
DEC17Q–NO CHROMO CONTROLLED AT 100, 10s

2.1 Hm/YAG, 1.0 W, SMALL APERTURE
DEC17R-2X ICG CONTROLLED AT 50, 10s

2.1 Hm:YAG, 1.0 W, SMALL APERTURE
DEC17T-2X ICG CONTROLLED AT 70, 10s

2.1 Hm:TAG, 1.0 W, SMALL APERTURE

-0.09913793 -0.7301724 -1.451724 -2.174138 -2.897845 -3.622845
DEC17U-2X ICG CONTROLLED AT 80, 10s

2.1 Hm:YAG, 1.0 W, SMALL APERTURE
DEC17V-2X ICG SET AT 100, TC MAX=90,
2.1 Hm:YAG, 1.0 W , SMALL APERTURE
DEC17W - 2X ICG UNWELDED CONTROL

2.1 Hm:YAG, 1.0 W, SMALL APERTURE

-0.010344830.7288793 - 1.447414 - 2.168104 - 2.889224 - 3.611207 - 4.332759 - 5.055604
DEC 17 - BLOOD CONTROLLED AT 50, 10 s

2.1 Hz: YAG, 1.0 W, SMALL APERTURE

-0.01034483 -0.7293103 -1.448707 -2.170259 -2.892672 -3.614655
DEC17Z—BLOOD CONTROLLED AT 60, 10s

2.1 Hm:YAG, 1.0 W, SMALL APERTURE

-0.01034483 -0.7280172 -1.446983 -2.165949 -2.8875 -3.60819 -4.329311
DEC17AA - BLOOD CONTROLLED AT 70, 10s
2.1 Hm:YAG, 1.0 W, SMALL APERTURE

-0.0099137930.9672414 -1.926724 -2.888362 -3.850862 -4.813793 -5.777156
DEC17AB - BLOOD CONTROLLED AT 80, 10 s
2.1 Hm:YAG, 1.0 W, SMALL APERTURE

-0.009913793 -0.9655172 -1.922845 -2.881897 -3.842672 -4.804311
DECO17AC--BLOOD CONTROLLED AT 100, 10 s

2.1 Hz YAG, 1.0 W, SMALL APERTURE

-0.01034483 -0.9637931 -1.918535 -2.876293 -3.836215 -4.792672
DEC18A – ONE STRIP UNWELDED CONTROL

2.1 Hz:YAG, 5.0 W, SMALL APERTURE

DEC18C - INDIA INK UNWELDED CONTROL

2.1 Hz:YAG, 5.0 W, SMALL APERTURE
DEC18E1—INDIA INK CONTROLLED AT 60, 10s

2.1 Hz, YAG, 5.0 W, SMALL APERTURE

-0.01810345 -0.7530173 -1.484914 -2.218966 -2.953879 -3.689224
DEC18I - NO CHROM CONTROLLED AT 50, 10s

2.1 Hm:YAG, 5.0 W, SMALL APERTURE
DEC18J–NO CHROMO CONTROLLED AT 60, 10s

2.1 Hm:YAG, 5.0 W, SMALL APERTURE

-0.009482758  -1.48319  -2.959483  -4.438362  -5.918966
DEC18L-NO CHROMO CONTROLLED AT 70, 10 s

2.1 Hm:YAG, 5.0 W. SMALL APERTURE
DEC18N-NO CHROMO-CONTROLLED AT 80, 10 s

2.1 Hm YAG, 5.0 W, SMALL APERTURE
DEC18Q- 2X ICG UNWELDED CONTROL

2.1 Hm: YAG, 5.0 W, SMALL APERTURE
DEC18R- 2X ICG CONTROLLED AT 50,10 s
2.1 Hm:YAG, 5.0 W. SMALL APERTURE
DEC18S  2X ICG CONTROLLED AT 60, 10 s

2.1 Hm:YAG, 5.0 W, SMALL APERTURE
DEC18U-2X ICG CONTROLLED AT 80, 10s

2.1 Hm:YAG, 5.0 W, SMALL APERTURE

-0.009482758 -1.209483 -2.410776 -3.616379
DEC18V- 2X CIG CONTROLLED AT 100, 10s

2.1 Hm: YAG, 5.0 W, SMALL APERTURE
DEC18W1 - 2X ICG CONTROLLED AT 80, 10s

2.1 Hm:YAG, 5.0 W, SMALL APERTURE
DEC 18X - BLOOD UNWELDED CONTROL

2.1 Hm: YAG, 5.0 W, SMALL APERTURE
DEC18AA - BLOOD CONTROLLED AT 60, 10s
2.1 Hm:YAG, 5.0 W, SMALL APERTURE

To -0.009482758 -1.212931 -2.419397 -3.629741 -4.839656
DEC18AB - BLOOD CONTROLLED AT 70, 10 s

2.1 Hz:YAG, 5.0 W, SMALL APERTURE
DEC18AD - BLOOD CONTROLLED AT 100, 10 s

2.1 Hm YAG, 5.0 W, SMALL APERTURE

-0.009482758 -1.212069 -2.417673 -3.625862 -4.836207
DEC19A - ONE STRIP UNWELDED CONTROL

808 DIODE, 0.15 W, SMALL APERTURE

-10
-0.02025862 -1.953448 -3.884052 -5.810776 -7.729311 -9.642672
DEC19C—TWO STRIP 2X ICC UNWELDED CONTRO

808 DIODE, 0.15 W, SMALL APERTURE

-3.2
-3.1
-3.0
-2.9
-2.8
-2.7
-2.6
-2.5
-2.4
-2.3
-2.2
-2.1
-2.0
-1.9
-1.8
-1.7
-1.6

-0.009051723 -0.7155173 -1.426293 -2.141811 -2.860345 -3.581897
DEC19D-2X ICG SET=50, TC MAX=20

808 DIODE, 0.15 W, SMALL APERTURE
DEC19F–ONE STRIP UNWELDED CONTROL
2.1 Hm:YAG, 5.0 W, LARGE APERTURE

0 10 20 30 40 50 60 70 80 90

-0.009482758 -3.602586 -7.219827 -10.81509 -14.38578
DEC19H—NO CHROMO CONTROLLED AT 50, 10 s

2.1 Hm:YAG, 5.0 W, LARGE APERTURE
DEC191 - NO CHROMO CONTROLLED AT 60, 10s

2.1 Hm:YAG, 5.0 W. LARGE APERTURE
DEC19J—NO CHROMO CONTROLLED AT 70, 10 s

2.1 Hm: YAG, 5.0 W LARGE APERTURE
DEC19K - NO CHROMO CONTROLLED AT 80

2.1 Hm:YAG, 5.0 W, LARGE APERTURE
DEC19L-NO CHROMO CONTROLLED AT 100, 10s

2.1 Hm: YAG, 5.0 W, LARGE APERTURE

-0.009051723 -2.398276 -4.836638 -7.280173 -9.718534
DEC19M - NO CHROMO CONTROLLED AT 50, 10s

2.1 Hm: YAG, 5.0 W, LARGE APERTURE
DEC19N- INDIA INK UNWELDED CONTROL
2.1 Hm:YAG, 5.0 W, LARGE APERTURE

-0.009051723 -0.9534483 -1.904311 -2.863362 -3.829741
DEC190-INDIA INK CONTROLLED AT 50, 10s

2.1 Hm: YAG, 5.0 W, LARGE APERTURE
DEC19P1—INDIA INK CONTROLLED AT 50, '0s

21 Hm:YAG. 5.0 W, LARGE APERTURE
DEC19S - INDIA INK CONTROLLED AT 80, 10s

2.1 Hm:YAG, 5.0 W, LARGE APERTURE

-0.009482758 -1.947414 -3.911638 -5.892242 -7.872845 -9.852156
DEC19U-2X iCG UNWELDED CONTROL

2.1 Hm:YAG, 5.0 W, LARGE APERTURE
DEC19V- 2X ICG CONTROLLED AT 50, 10s

2.1 Hm:YAG, 5.0 W, LARGE APERTURE
DEC19W-2X ICG CONTROLLED AT 60, 10s

2.1 Hm:YAG, 5.0 W, LARGE APERTURE
DEC19X-2X ICG CONTROLLED AT 70, 10s

2.1 Hm:YAG, 5.0 W, LARGE APERTURE
DEC19Y - 2X ICG CONTROLLED AT 80, 10s

2.1 Hm: YAG, 5.0 W, LARGE APERTURE

-0.009482758  1.47931  -2.965086  -4.464225  -5.971552
DEC19Z-2X ICG CONTROLLED AT 100, 10s

2.1 Hm-YAG, 5.0 W, LARGE APERTURE
DEC21A–ONE STRIP UNWELDED CONTROL

2.1 Hm: YAG, 4.8 W, LARGE APERTURE

-0.02025862 -3.728879 -7.453017 -11.15474 -14.83276
DEC21AA1—NO CHROMO CONTROLLED AT 70,10s

2.1 Hm:YAG, 1.5 W, LARGE APERTURE
DEC21AB—NO CHROMO CONTROLLED AT 80, 10s

2.1 Hm:YAG, 1.5 W, LARGE APERTURE
DEC21AC—NO CHROMO CONTROLLED AT 100, 10s

2.1 Hm:YAG, 1.5 W, LARGE APERTURE
DEC21AD - INDIA INK UNWELDED CONTROL

2.1 Hz: YAG, 1.5 W, LARGE APERTURE

-0.009913793 -1.468535 -2.941379 -4.425
DEC21AE--INDIA INK CONTROLLED AT 50, 10s

2.1 Hm YAG, 1.5 W, LARGE APERTURE
DEC21AH--INDIA INK CONTROLLED AT 80, 10s

2 1 mm YAG, 1 5 W, LARGE APERTURE

-0.009913793 -1.214224 -2.428017 -3.651293 -4.880604
DEC21B-TWO STRIP UNWELDED CONTROL
2.1 HH: YAG, 48 W, LARGE APERTURE

-0.009913793 -1.234052 -2.467672 -3.709483
DEC21C-TWO STRIP 2x ICG UNWELDED CONTRO

2.1 Hm:YAG, 4.8 W, LARGE APERTURE

-0.009913793 -1.236207 -2.47069 -3.713362
DEC21D-2X ICG CONTROLLED AT 50, 10s

2:1 Hm:YAG, 4.8 W, LARGE APERTURE
DEC21AI—INDIA INK CONTROLLED AT 100,10s

2.1 Hz: YAG, 1.5 W, LARGE APERTURE
DEC21E-2X ICG CONTROLLED AT 60, 10s

2.1 Hm:YAG, 4.8 W, LARGE APERTURE
DEC21F-2X ICG CONTROLLED AT 70, 10s

2.1 Hm:YAG, 4.8 W, LARGE APERTURE

[Graph with data points and values]
DEC21H–BLOOD UNWELDED CONTROL

2.1 Hz YAG, 4.8 W, LARGE APERTURE
DEC21J-BLOOD CONTROLLED AT 50, 10s

2.1 Hm: YAG, 4.8 W, LARGE APERTURE
DEC21K—BLOOD CONTROLLED AT 60, 10s

2.1 Hm:YAG, 4.8 W, LARGE APERTURE
DEC21L - BLOOD CONTROLLED AT 70, 10s
2.1 Hm: YAC, 4.8 W, LARGE APERTURE
DEC21M- BLOOD CONTROLLED AT 80, 10s

21 Hm: YAG, 4.8 W, LARGE APERTURE
DEC21N—BLOOD CONTROLLED AT 100, 10s

2.1 Hz YAG, 4.8 W, LARGE APERTURE
DEC2101—BLOOD CONTROLLED AT 50, 10s

2.1 Hz YAG, 1.5 W, LARGE APERTURE

-0.02025862 -2.487931 -4.982759 -7.487069 -9.983189
DEC21P - BLOOD CONTROLLED AT 60, 10s

2.1 Hm:YAG, 1.5 W, LARGE APERTURE

-0.009482758 -0.988362 -1.972845 -2.962931 -3.95819
DEC21Q - BLOOD CONTROLLED AT 70, 10s

2.1 Hm: YAG, 1.5 W, LARGE APERTURE
DEC21T-2X ICG CONTROLLED AT 50, 10s

2.1 Hm:YAG, 1.5 W, LARGE APERTURE

-0.009482758, -1.462069, -2.927155, -4.405604, -5.888362, -7.371121
DEC21S—BLOOD CONTROLLED AT 100, 10s

2.1 Hm•yAG, 1.5 W, LARGE APERTURE
DEC21V-2X ICG CONTROLLED AT 70, 10s

2.1 Hm:YAG, 1.5 W, LARGE APERTURE
DEC21W-2X ICG CONTROLLED AT 80, 10s

2.1 Hm:YAG, 1.5 W, LARGE APERTURE
DEC21X-2X ICG CONTROLLED AT 100, 10s

2.1 Hm:YAG, 1.5 W, LARGE APERTURE

-0.008620689  -1.943103  -3.899569  -5.871121  -7.843535
DEC21Y-NO CHROMO CONTROLLED AT 50, 10s

2.1 Hm:YAG, 1.5 W, LARGE APERTURE
Appendix B- Excluded Data
File Input/Output

File Name: <B:AUG28V.USR>

Quit/Continue: *  

8 Comments

Subfiles (total #: 7):

1> FERRONYL, 100 DEGREES CONTROLLED
2> SOME BLANCHING
3> ONE OF THE BEST WELDS TODAY

FERRONYL, 100 DEGREES CONTROLLED
Start# Shape #Repts:
1 2 x 256 7
File Name: <B:AUG28W.USR>

8 Comments

- FERRONYL, 50 DEGREES CONTROLLED
- NO VISUAL CHANGES
- NOT A VERY GOOD WELD
- BURLEIGH STAGE DID NOT MOVE AT THE BEGIN:

8 Comments

- FERRONYL, 50 DEGREES CONTROLLED
- NO VISUAL CHANGES
- NOT A VERY GOOD WELD
- BURLEIGH STAGE DID NOT MOVE AT THE BEGIN:

> FERRONYL, 50 DEGREES CONTROLLED
> NO VISUAL CHANGES
> NOT A VERY GOOD WELD
> BURLEIGH STAGE DID NOT MOVE AT THE BEGIN:
File Name: <B:AUG28X.USR>

8 Comments

1> FERRONYL-60 DEGREES CONTROLLED
2> NO VISUAL CHANGES
3> ONE OF THE BETTER WELDS
File Name: <B:AUG28Y.USR>

8 Comments

1> INDIA INK, TEMP CONTROLLED AT 60
2> SLIGHT DESSICATION
3> A GOOD WELD
4> LOOKS BETTER THAN FERRONYL

Comments Subfiles (Total #: 4)

INDIA INK, TEMP CONTROLLED AT 60
SLIGHT DESSICATION
A GOOD WELD
LOOKS BETTER THAN FERRONYL

Quit/Continue: *
Temp = 600

India Ink

L0yp 6y950

File Name: <B:AUG28AB.USR>

INDIA INK, 60 DEGREES, LARGE APERTURE, 1 x 2.56

WELDED, ONE OF THE BETTER WELDS

Subfiles (Total #: 7)
1
2 x 256

Quit/Continue:*
File Name: <B:AUG28AA.USR>

8 Comments

Subfiles (Total #: 5):
1. LARGE APERTURE, INDIA INK, 50 DEGREES
   Start #: Shape   #Repts:
   1        2 x 256  5
2. WELDED

Aug 28 AA

Large Aperture
India Ink
Temp = 50
File Name: <B:AUG280.USR>

8 Comments

1> FERROXIL, TEMP SET = 80 DEGREES, TC MAX = Start#
2> TOO DEEP.
3> NOT A GREAT WELD

Date: AUG 280
File Name: <B:AUG28BR.USR>

8 Comments

1> REPEAT FERRONYL-TEMP = 80
2> BETTER TC PLACEMENT
3> SOME BLANCHING
4> WELDED

Subfiles (Total #: 7):

<table>
<thead>
<tr>
<th>Start#</th>
<th>Shape</th>
<th>#Repts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 x 256</td>
<td></td>
</tr>
</tbody>
</table>
File Name: <B:AUG285.USR>

8 Comments

1) FERRONYL TEMPERATURE AT 100 DEGREES
2) SOME BLANCHING AND DESSICATION
3) WELD WAS NOT VERY STRONG

Quit/Continue: *
File Name: <B:AUG26U.JSR>

8 Comments

Subfiles (Total #: 7)

1) FERRONYL, TEMP SET AND CONTROLLED AT 80 D: Start# Shape #Repts:
   1  2 x 256  7

2) GES

3) LOOKED STRONGER THAN THE 70 DEGREE AND ST:

4) WELDS FROM THIS MORNING.

Av. of 2S U

Ferronyl
Temp = 80°
File Name: <B:AUG28K.USR>

Quit/Continue: *

8 Comments

1. INDIA INK, 70 DEGREES (NOT REACHED) SOME

2. WELDED, BROKE APART AT SEROSAL SURFACE.

3. WELD SEEMED TO EXTEND THROUGHOUT TISSUE.

AUG 28K

India Ink Temp - 75
File Name: AUG28USR

Comments:
1) India Ink, Temperature Set at 100 and Con.
Start# Shape #Reps
2) Looked like a good weld

Graph:
- X-axis: Time (0-100 sec)
- Y-axis: Temperature (20.0, 1.0 degrees)
- Data points indicate a consistent temperature of 100 degrees until 70 seconds, then a sharp drop to 0 degrees.

Handwritten note:
India Ink Temp = 100

August 28, 1989
File Name: B:AUG28N.IUSR

8 Comments

Subfiles (Total #: 7)

1) FERRONYL TEMP = 50 CONTROLLED AT 41 DEGRE: Start# Shape #Repts:
   1 2 x 256 7

2) SOME BLANCHING LOOKS LIKE A WELD
8 Comments

1. FERRONYL 70 DEGREES LITTLE DESSICATION AN: Start# Shape #Repts:
2. A WELD, STRONGER THAN 60 DEGREES, BUT NOT:
3. FERRONYL BARELY VISIBLE

Temp = 30°
8 Comments

1> FERRONYL COMPOUND
2> 10 SECONDS
3> SMOKED
4> WELDED OR STUCK TOGETHER

Quit/Continue: *

Subfiles (Total #: 5)

- File Name: <B:AUG28E.USR>

Comments

- Subfiles
- (Total #: 5)

- Start# Shape #Repts
- 1 2 x 256 5

- Date: Aug 28 3
File Name: (B:AUG28F.USR)

8 Comments

Subfiles (Total #: 4)

1> LIGHT INDIA INK, DRIED TISSUE, CONTROLLED: Start# Shape #Repts:
   : 1 2 x 256 4

2> NOT MUCH OF A WELD

NOT MUCH OF A WELD
File Name: <B:AUG28G.USR>

Subfiles (Total #: 6)

1. LIGHT INDIA INK, DRIED WITH Q TIP, NEW BO:
   - Start:
   - Shape:
   - #Repts:

---

Light

New

No clamp
File Name: <B:AUG28H.USR>  
Quit/Continue: *

8 Comments

Subfiles (Total #: 5)

1> NEW BOWEL WITH CLAMPS, LIGHT INDIA INK, D: Start# Shape #Repts:
2> THERMOCOUPLE PLACEMENT NOT CORRECT-ALIGN:
3> CLAMPS ARE INTERFERING WITH EXPT.

NEW BOWEL WITH CLAMPS, LIGHT INDIA INK, D: Start# Shape #Repts:
2> THERMOCOUPLE PLACEMENT NOT CORRECT-ALIGN:
3> CLAMPS ARE INTERFERING WITH EXPT.

AUG 28H

Light India

with clamp

Red bowd
File Name: <B:AUG281.USR>  

dict

Subfiles (Total #: 8) :  
  1> TEMP AT 50 DEGREES, LIGHT INDIA INK, NO C: Start# Shape #Repts :  
  2> WELDED

Quit/Continue: *
File Name: <B:AUG28C.USR>

Comments

Subfiles (Total #: 4)

DID NOT LOOK LIKE MUCH OF A WELD

Laser control - 2 ships
File Name: <B:AUG28D.USR>

Quit/Continue: *

Subfiles (Total #: 4)

<table>
<thead>
<tr>
<th>Start</th>
<th>Shape</th>
<th>#Repts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 x 256</td>
<td>4</td>
</tr>
</tbody>
</table>

INDIA INK LIGHT

NOT A GOOD WELD

Aug 2-70
Summary

Annual Analysis Discussion

Tc peak = 5.7

Figures and Set = 50

SEP SP
The DIPOLE CHARGE

E0

E0
Very weak recoil
No visible changes
Ampl. unit controller again
PEP 55
There is a graph with the following axes:

- Y-axis: -15.0 to 25.0
- X-axis: -1.00 to 7.00

The graph shows a sharp peak at around x = 0.5 and then decreases towards zero.
I/0 Variable (R - Z): 512 REAL

Subfile: 2 x 256 (Max. Length: 768)
Row (O=all): < 1
Start Column: < 1
N of Columns: < 256

Read/Write/Append/Scroll/Plot/Edit/List/New file/Quit: #
File Name: <B:SEP12B.USR>

1) ONE STRIP CONTROL
   Start#  Shape   #Repts:
   1       2         4

2) NO SLIPPAGE

3) Small Slippage

4) SW

I/O Variable (R-Z):
   512 REAL

Subfile:
   <1>  Z = 256 (Max Length: 1024)
   <2>  Row (0=all): <0>
   <3>  Start Column: <1>
   # of Columns: <256>

Read/Write/Append/Scroll/Plot/Edit/List/New file/Quit: #
File Name: (B:SEF12D,USR)

File/Output

Comments

Subfiles (total #: 2)

1) INDIA INK CONTROLLED AT 5m
   Start# Shape #Hearts:
   1 2 256 2

2) LOOKS LIKE A WELD

3) NO SMOKE

4) NO BLANCHING

5) WEAK WELD

6) SMALL APERTURE

7) SW

8) 

Subfile: (1)

Row (O=all): < 0

Start Column: < 1

# of Columns: 256

Read/Write/Append/Scroll/Plot/Edit/List/New file/Quit: #
File Name: <B:SP12EUSR  

Comments Subfile (Total #: 5) 

1. INDIA INK SMALL APERTURE 
2. CONTROLLED AT 60 
3. NO VISUAL CHANGES 
4. WEAK WELD 
5. SMALL APERTURE 
6. SW 

I/O Variable (R - Z): 

Subfile:  

Row (Max): < 0 > 

Start Column: < 1 > 

# of Columns: < 256 > 

Read/Write/Append/Scroll/Plot/Edit/List/New file/Quit: 

13.2
15.7
17.7
19.7
21.7
File Name: <BiSEP12F.USR>

Comments:

1. INDIA INK CONTROLLED AT 70
2. SLIGHT DESSICATION
3. TORE APART FROM SEKUSA
4. MEDIUM STRONG WELD
5. SMALL SEPARATE
6. SW
7. 
8. 

I/O Variable (R = 1):

Subfile: <1>
Row (small): <0>
Start Columns: <1>
# of Columns: <256>

Read/Write/Append/Scroll/Sort/Edit/List/New File/Quit:
File Name: (E:SEF12H.USR)

Comment:

1. INDIA INK CONTROLLED AT 100
2. VERY MINIMAL DESICCATION
3. SMALL APERTURE
4. DID NOT APPEAR TO BE HELD
5. SW
6.
7.
8.

Subfile: 1
Row (or all): 0
Start Column: 1
# of Columns: 256

Read/Write/Append/Scroll/Plot/Edit/List/New file/Quit:
**File Name:** <B:SEF121.USK>

**Comments:**

1. *INDIA INK, CONTROLLED AT 100*
2. *TC PLACED DEEPER THAN PREVIOUS RUN*
3. *DESSICATION, SMELL'S CURED*
4. *STILL LOOKS WEAK*
5. *SMALL APERTURE*

**I/O Variable (R-Z):**

<table>
<thead>
<tr>
<th>Subfile</th>
<th>Row 0=all</th>
<th>Start Column</th>
<th># of Columns</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>0</td>
<td>1</td>
<td>&lt;256</td>
</tr>
</tbody>
</table>

*Read/Write/Append/Scroll/Plot/Edit/List/New file/Quit:*
INDIA INK CONTROLLED AT 5W

NOT MUCH OF A SMALL APERTURE

WEAK WELD

5W

I/O Variable (R-Z): 768 REAL

Subfile: 1

Row (Real): 0

Start Column: 1

# of Columns: 256

Read/Write/Append/Scroll/Plot/edit/List/New file/Quit:
File Name: (RESERCH.LUSK)

Comments:

I/O Variable (R-Z):

Subfile:

Row (0=all): 0

Start Column: 1

# of Columns: 256

Read/Write/Append/Scroll, Plot/Edit/List/New file/Quit: #
MINIMAL DESSICATION
NOT IMPRESSIVE
Variable (R -- Z ! 6~!-~

File Name: C:ISEFICATION.  Quit/Continue: *

INDIA INK CONTINUED AT 0
SLIGHT DESSICATION
MINIMAL BLANCHING
LOOKED LIKE A KAIN
NO SMOKE

I/O Variable (R-Z): 768 REAL
Subfile: 1
Row (0=all): 1
Start Column: 0
# of Columns: 256

Read/Write/Append/Scroll/Plot/Edit/List/New file/Quit: *
INDIA INK SET=B (TV)
SLIGHT DESSICATION
NO CARBONIZATION
SLIGHT BLANCHING
NO SMOKE
BO LEANED ON TABLE
NO EVIDENCE OF A HULL

Subfile: 1
Row (Start): 0
Start Column: 1
# of Columns: 256

Head/Write/Append/Scroll/Plot/Edit/List/New file/Exit
File Name: C:SET14\USP

8 Comments

1. INDIA INK SET=100, TC MAX=99
2. TOTAL TIME=255
3. DESSICATION AND BLENDING
4. NO SMOKE
5. STRONGEST AT THE PRESSURE SURFACE
6. BEST WELD SO FAR (INDIA)
7. INFO Variable (K = 7)
8. INFO Variable (K = 7)

Subfile: 2
Row (flows): 0
Start Column: 1
# of Columns: 256

Read/Write/Append/Scroll/Plot/Edit/List/New file/Quit:
INDIA INK CONTROLLED AT 10
SLIGHT SPACKLING
SLIGHT BLANCHING
NO DESSICATION
WEAK WELD
TORN AT SEROSA

1.0 Variable (1 – 2 h)

Subfile: 1
Row (=all): 0
Start Column: 1
* of Columns: 256

Read/Write/Append/Center: Initial display - noBLANKS

Sample Chart
| File Name: | LOGFILE1.JU | Location: |  |
| Comments: | 0 |  |
| INDIAN INDIAN CONTACT | 1 |  |
| SMALL EFFECT | 2 |  |
| BLANKING | 3 |  |
| NO CHOICE | 4 |  |
| NOT ENTERED | 5 |  |
| I/O Variable: | 6 |  |
| Subfile: | 7 |  |
| Row (Row): | 8 |  |
| Start Column: | 9 |  |
| No. of Columns: | 10 |  |
| Read/Write/Append | 11 |  |
File Name: CISEP18AE.USR

Quit/Continue:*

8 Comments

Subfiles (Total #: 3)

1. BLOOD BET=80 TC MAX=40
   Start#: 1
   Shape: 256
   #Repts:

2. TOTAL EXPOSURE =30 S
   1
   2 = 256

3. NO'S VISIBLE CHANGES

4. NO SMOKE

5. NO WELD

6. NO ...

I/O Variable ( R - Z )

Subfiles: 2 x 256 (Max: Length: 768)

Row (0=all): 21

Start Column: 1

# of Columns: 256

Read/Write/Append/Scroll/Plot/Edit/List/New file/Quit: #
Appendix C- Supplemental Figures and Illustrations
Figure 1- Thermocouple Placement

Laser
Fiber
Inverted Bowel
Stationary End
Thermocouple
Push

Laser
Fiber
Inverted Bowel
Weld Site
Stationary End
Thermocouple

Laser
Fiber
Inverted Bowel
Weld Site
Stationary End
Stain Gauge
Pull/Test
**Figure 2- Experimental Protocols**

**LASER TISSUE WELDING OPTIMIZATION PROTOCOL**

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Aperture Size (mm)</th>
<th>Power (W)</th>
<th>Chromophore</th>
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</tr>
</tbody>
</table>
Rabbit Animal Prep Protocol

Supplies Needed:

Alcohol Preps

1 ml Tuberculin Syringe

3 ml Syringe

#18 Needle

#22 Needle

Gemini Xylazine (Rompun)

Ketaset (Ketamine)

100 ml bag of 0.9% NaCl or 5% Dextrose in Water for intravenous use

Microdrip (60 drops per ml) dispenser and tubing

Animal Clippers

Manual (non-electric) Razor

Artificial Tears Ointment

#22 JELCO IV Catheter Placement Unit

Paper Tape

Beuthanasia (sodium pentobarbital or formerly known as Sleepaway)
Procedure:
1. One day prior to desired surgery, remove food container from rabbit's cage. Leave water bottle.

2. Prepare tray of surgical instruments for autoclaving. Place blue cloth drape under and over instruments. Add hemoclips, needle holders, atraumatic clamps, and other specialized instruments as needed. Autoclave instruments.

3. Collect all supplies listed above. Place in rabbit room.

4. Close door to rabbit room.

5. Determine amount of Rompun injection. A chart which indicates the appropriate amount to inject is appended to this document.


7. With syringe in hand, gently and quietly open door to selected rabbit's cage. Pet rabbit gently to reassure. After calming rabbit, obtain control over the animal by grasping firmly at the neck. Hold down rabbit and inject Rompun into the muscle in the hind quarter.

8. Close rabbit cage. Wait approximately 10 minutes for rabbit to become sedated. Rabbit may slouch or turn head to side.

9. Remove rabbit from cage, supporting head and neck carefully.

10. Transfer rabbit to sink.

11. Using chart in appended to this document and the actual weight of the rabbit, determine the appropriate amount of Ketaset to inject.

12. Prepare injection of Ketaset. Remove the 3 ml. syringe from its packaging and place the #18 needle on the end of the syringe. Wipe the septum of the Ketaset bottle with an alcohol prep, and insert syringe. Remove desired amount of Ketaset and then carefully change needles from the #18 to the #22. Grasp the rabbit firmly and inject Ketaset, using the #22 needle, into the hind quarter.

13. Wait approximately 10 minutes for the rabbit to become completely anesthetized. The rabbit is completely anesthetized when it can be picked up and placed on its back and does not attempt to turn itself over.

14. While waiting, prepare intravenous anesthetic cocktail. To the 100 ml. 0.9% NaCl bag add 4.0 ml. Rompun and 8.0 ml. Ketaset. Invert bag to mix. Hang bag on IV pole. Insert microdrip and tubing into bag and then remove plastic cover from distal end of tubing. Place three or four strips of paper tape on the IV pole for later use.

15. Place three or four paper towels on the countertop next to the sink and two paper towels inside the sink. Place rabbit, belly up, on the countertop.
16. Apply Artificial Tears to the rabbit's eyes to prevent painful drying.

17. Using a marker, number the rabbit by writing its identification number from the experimental protocol inside its ear.

18. Use electric clippers to shave appropriate area of rabbit, usually abdomen and groin. Push excess fur onto the paper towels. Quickly remove paper towels and fur as soon as clipping is completed.

19. With non-electric razor, gently remove hair from the ears, particularly along the external vein. This vein will be used for the intravenous anesthetic.

20. Transfer the rabbit to the surgical site.

21. Wipe the external ear vein region with an alcohol prep. This should improve visualization of the vein.

22. Remove JELCO catheter from its packaging. Insert catheter into the external vein. Use needle to enter vein and then pull back on the needle so that the catheter slides along the inside of the vein. Watch catheter slide inside the vein. Look for a backflow of blood into the top part of the catheter placement unit. Remove the needle completely when the catheter has been correctly positioned.

23. Attach the tubing from the IV bag to the top part of the catheter placement unit. Test catheter placement by slowly opening the anesthetic flow regulator and watching for anesthesia flow. Alternatively, open the saline regulator if one has been piggy-backed, and watch its flow. When adequate placement is verified, carefully tape the tubing and the catheter placement unit to the rabbit's ear. Tape excess tubing to the table.

24. Adjust the anesthetic flow rate to 1 drop every 4 seconds. Watch the rabbit's chest rise and pupil size to monitor anesthesia. If rabbit begins to come out of the anesthesia, increase rate to 1 drop every 2 seconds for about 1 minute. Return to 1 drop every 4 seconds, and wait until rabbit is sedated (1-2 minutes).

25. If rabbit is to be euthanized, inject 4.0 ml. of 1:1 diluted Beuthanasia into the septum of the IV line. The bottle will indicate if it has already been diluted. If it has not been diluted, mix equal parts of concentrated Beuthanasia and 0.9% NaCl, and inject this solution into the IV line. Do not inject concentrated Beuthanasia into the IV line because it is very viscous, and therefore, it is difficult to force it out of the tubing and into the rabbit.

26. After rabbit has died, remove IV line and place rabbit remains into a large brown plastic bag.

27. Carefully wash instruments. Alconox or similar detergent should be used. Never leave instruments soaking in water. Rinse instruments and place them on a towel to dry.
RABBIT ANESTHESIA

INITIAL INTRAMUSCULAR DOSE OF XYLAZINE GIVEN, FOLLOWED 10 MINUTES LATER BY AN INTRAMUSCULAR DOSE OF KETAMINE. DOSAGE BASED ON WEIGHT OF RABBIT.

<table>
<thead>
<tr>
<th>WEIGHT (LBS.)</th>
<th>XYLAZINE 20 MG/ML</th>
<th>KETAMINE 100 MG/ML</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.5</td>
<td>0.72</td>
</tr>
<tr>
<td>4.25</td>
<td>0.53</td>
<td>0.77</td>
</tr>
<tr>
<td>4.5</td>
<td>0.56</td>
<td>0.81</td>
</tr>
<tr>
<td>4.75</td>
<td>0.59</td>
<td>0.86</td>
</tr>
<tr>
<td>5</td>
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</tr>
<tr>
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<td>0.66</td>
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</tr>
<tr>
<td>5.5</td>
<td>0.69</td>
<td>0.99</td>
</tr>
<tr>
<td>5.75</td>
<td>0.72</td>
<td>1.04</td>
</tr>
<tr>
<td>6</td>
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</tr>
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<td>0.78</td>
<td>1.13</td>
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<tr>
<td>6.5</td>
<td>0.81</td>
<td>1.17</td>
</tr>
<tr>
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<td>1.22</td>
</tr>
<tr>
<td>7</td>
<td>0.88</td>
<td>1.26</td>
</tr>
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</table>

INTRAOPERATIVE ANESTHESIA CONSISTS OF 4 MG KETAMINE + 2 MG XYLAZINE IN 50 ML DILUENT, INFUSED AT 1 DROP EVERY 4-6 SECONDS FOR A 6-8 LB. RABBIT.
Tissue Preparation for Weld Strength Optimization Study

1. Make a midline incision with a #15 scalpel.
2. Identify and isolate the small bowel.
3. Place an atraumatic clamp across the mesentery at the section to be resected.
4. Place a hemoclip at the site of the nearest vessels to occlude blood flow.
5. Resect a small segment of bowel measuring approximately 5 cm.
6. Return the remaining in situ bowel to the abdomen.
7. Make a longitudinal cut in the bowel segment, and open it up. Carefully rinse the bowel segment in physiological saline to remove succus entericus.
8. Using the specialized cutters, cut two strips measuring 4.0 x 20.0 mm. Place the two strips into the clamps, making sure that the strips are aligned relative to the marks on the clamps.
9. Apply a barely visible amount of chromophore with a cotton-tipped applicator. The chromophore should be applied to both tissue strips.
10. Position the thermocouple between the two tissue strips.
11. Slowly bring the two tissue strips into apposition using the computer-controlled piezoelectric motor.
12. Verify appropriate thermocouple placement (1 mm below surface of weld).
14. Switch to the tensiometry data acquisition program. Pull tissue apart and measure the load required to rupture the weld.
15. Repeat steps 5-14 to prepare additional tissue strips.
16. Import data into Lotus or Symphony to generate load versus distance plots.