

**MECHANICAL SUPPORT DEPARTMENT**  
**ENGINEERING NOTE**

NUMBER: MSD EN-5.0

DATE: 26 May 1995

TITLE: KTEV 1.8 meter Vacuum Window Testing Procedure for vacuum and hydrostatic tests and test results

AUTHOR(s): Andrew Szymulanski

REVIEWED BY: KTEV Mechanical Safety Review Panel, Joel Misek, Chairman

DATE REVIEWED: March 21, 1994

KEY WORDS: KTEV Vacuum Window structural components, Stress Analysis  
Vacuum test, Hydraulic test

**ABSTRACT/SUMMARY:**

This documentation contains an engineering analysis for some of the structural elements used during the testing. It also shows results of the vacuum, hydrostatic and impact tests. Three out of the four hydrostatic tests yielded an effective safety factor of 2 for the tested window assembly.

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KTeV 1.8 m VACUUM WINDOW

PART A

1.8 m VACUUM WINDOW  
TESTING PROCEDURE  
FOR VACUUM AND HYDROSTATIC  
TESTS

ANDREW SZYMULANSKI

RD / MSD

MARCH 8.94

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KTEV  
E-832

1.8 m VACUUM WINDOW TESTING PROCEDURE  
FOR VACUUM AND HYDROSTATIC TESTS.

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12. MATERIAL SAFETY DATA SHEETS:

a) KEVLAR

b) MYLAR

R. Currier  
A. Szymulanski  
March 8, 1994

## KTeV 1.8m Vacuum Window Overview of Test Procedure

This test is required to provide a suitable, safe, non metallic vacuum window for the KTeV experiment, which is running during the next fixed target run. To determine if the design of this window meets all of the parameters of the experiment and the KTeV ES&H Review Committee, the following set of tests were devised. The first test, initial pump down, proves that the window design works. The puncture test will give us an idea how the window will fail, if a hole were to develop (material failure), or was accidentally penetrated. The initial pump down and puncture test will require a single pressure test permit. The hydrostatic test is intended to give us an idea of the safety factor of the window and will require a separate pressure test permit. The long duration creep test will give us information on how the window survives or fails over a long period of time. If there are any deviations from expected results during any test, the tests will be stopped until the deviation can be understood then explained in writing to the KTeV ES&H Review Committee, exactly what happened, why, and how it will affect the rest of the test program. Interesting phases of the test should be put on video tape. Present at the beginning of each phase of the tests should be a representative of the ES&H Dept, the KTeV experiment, the KTeV ES&H Review Committee, Don Carpenter and Andrew Szymulanski.

### Safety considerations:

- A) During the vacuum test, no one will be allowed within 10 feet of the test vessel. This is to be assured by roping off the test area, appropriate signs, (keep-out test in progress), and supervisory vigilance.
- B) Safety glasses and safety shoes are requirements of anyone working at MAB. Test observers will be required to wear safety glasses at all times.
- C) Hearing protection will be required of all personnel in the building during the initial pump down, subsequent pump downs and during the puncture test only.

1) Make a kevlar and aluminized mylar, sandwiched window, and assemble with flanges etc. as specified on Dwg.# MD-285394 and attached information. Inform Andrew when starting, so the KTeV ES&H Review Committee and the experiment can be notified.

2) Set up for vacuum test as shown on Dwg.#MD-285391 and schematic attached. Arrange for surveyors.

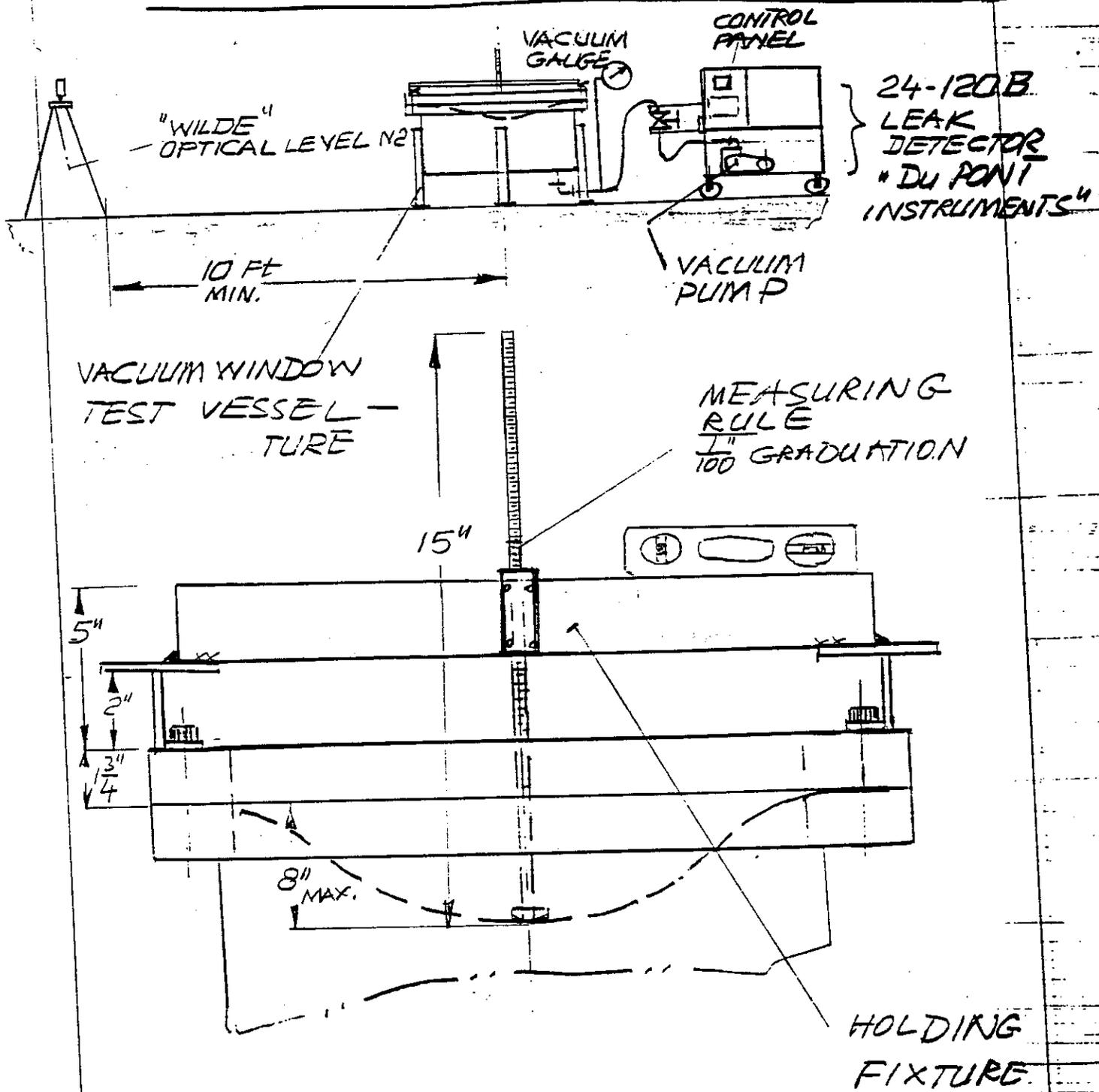
2a) Prepare for pump down by clearing the test area and setting up as specified in A) above. Check for eye and hearing protection and display pressure test permit.

2b) Pump down test chamber to a minimum of 29" Mercury(Hg) and remotely measure and record the deflection of the window every 2 hours. The remote measuring is to be accomplished by using optical surveying instruments looking at the scale mounted in the center of the thin window as shown on page 7B. Shut down overnight and bleed up to atmosphere. Pump down again in the AM recording the deflection every 2 hours. Shut down overnight and bleed up to atmosphere. Pump down again in the AM to 29" Hg then shut down and bleed up to atmosphere.

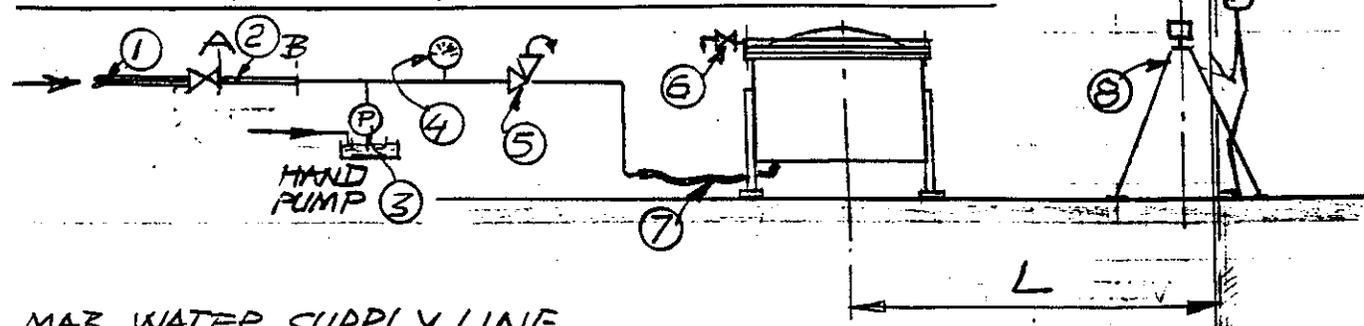
- 3) Using the same window, prepare for puncture test. Follow the design data of sketch 1'.
  - 3a) Prepare for pump down and puncture test by clearing the test area and setting up as specified in A) above. Check for eye and hearing protection and display pressure test permit.
  - 3b) Set up puncture device as shown on attached sketch, start pumping down test chamber. At 29" of Hg.
  - 3c) After double checking all of the appropriate safety precautions, remotely release spear to puncture window.
  
- 4) Assuming the first window worked, make a second window and proceed to Hydraulic test. Notify surveyors.
  
- 5) Set up for hydrostatic test inside the MAB shop per schematic attached. Assemble test chamber and place 2 legs on a 4 x 4 to elevate bleed valve (as shown on attached sketch). Make sure to display pressure test permit.
  - 5a) Fill test chamber with water (make sure bleed valve is open.) After filled, lift chamber with crane using appropriate slings and rigging techniques. Remove 4 x 4s from under legs. (as shown on attached sketch)
  - 5b) Prepare for hydrostatic test by clearing the test area and setting up as specified in A) above. Check for eye protection.
  - 5c) Pressurize test chamber, as shown in subsection 3, using a hydrostatic tester pump, to 15psig then carefully measure the window deflection. Continue to add pressure and remotely measure deflection at 5psig increments, to destruction of window or 45psig whichever comes first. (failure expected at 31psig to 38psig)
  - 5d) Clean up mess, then disassemble window flanges and check window, o-ring, and aluminum ring for irregularities.
  
- 6) Using information learned from the fabrication of the first windows, make another window for the long duration, 6 month, creep test.
  - 6a) Find an area in the shop, out of the normal traffic pattern, away from people and well protected from casual contact to set up the test chamber and new window.
  - 6b) Prepare for pump down and long duration creep test by clearing the test area and setting up as specified in A) above.
  - 6c) For the duration of the test, maintain the area to the same degree of security and safety as originally set up.
  - 6d) Test chamber and window are to be under vacuum, with vacuum pump running, 24 hours a day 7 days a week.
  - 6e) Bleed up to atmosphere once per month, over the weekend only.
  - 6f) Record the pressure level in a log at the start and the finish of each working day for the duration of the test. It's not necessary to use a strip chart recorder.

- 6g) It is possible that the window will creep, or move, or maybe even stretch, over a period of time. The result would be an increase in deflection. If the measured deflection is ever greater than the original by 1/4" notify Andrew.
- 6h) Remotely measure and record the deflection of the window each day for the first week.
- 6j) If a measurable change is not indicated during the first week then measure and record the deflection of the window at the end of the first and last day of the second week.
- 6k) If a measurable change is not indicated at the end of the second week then measure and record the deflection of the window at the end of first day of each week for the duration of the test.
- 6m) The duration of the test is expected to be 6 months.
- 6n) If any peculiarities or problems are encountered, call Andrew @ x4870.

# 2. TESTING SYSTEM SCHEMATIC - VACUUM



3. TESTING SYSTEM SCHEMATIC - HYDROSTATIC



- 1. M.A.B. WATER SUPPLY LINE  
MAX. PRESSURE 65 [psi]
- 2. WATER FLOW CAPACITY CONTROL  
SECTION "A - B"  $\frac{1}{8}$ " SCH 40 PIPE  
INSIDE DIA : 0.269"
- 3. HAND PUMP
- 4. PRESSURE GAUGE  
"WEISS" 0 TO 100 psi
- 5. RELIEF VALVE (WATER)  
SET PRESSURE 40 psig  
CAPACITY 18 GAL/min  
@ 10% OVERPRESSURE  
TELEDYNE-FARRIS TYPE 1850,  $1\frac{1}{2}$ "
- 6. BLEED VALVE

- 7. FLEXIBLE HOSE  
 $\frac{1}{4}$ " , 400 psi RATING
- 8. WILDE OPTICAL  
LEVEL N2

DIMENSION "L" HAS TO BE LARGER OR EQUAL 10 Ft  
FOR VACUUM TEST BUT MAY BE CLOSER THAN 10  
FOR HYDROSTATIC TEST.

• DETERMINE THE FLOW RATE IN  $\frac{1}{8}$ " PIPE, SECTION "A-B"  
(ITEM 2).

GIVEN DATA: MAX. PRESSURE IN THE M.A.B.  
SUPPLY LINE = 65 [psig]  
INSIDE DIA OF THE "A-B" SECTION  
 $d = 0.269$ "

ASSUMED NO FRICTION IN THE PIPE.

$p = 65 \text{ psi} = 150 \text{ Ft of } H_2O$   
FROM BERNOULLIS EQUATION:  
 $\frac{v^2}{2g} = 150$   
 $v$  - WATER VELOCITY IN THE PIPE  
 $g$  - GRAVITY ACCELERATION

$v = \sqrt{150(2) 32.2}$   
 $v = 98.28 \text{ Ft/sec}$   
FLOW CAPACITY:  
 $Q = A \cdot v$   
 $A = \frac{\pi d^2}{4} = 0.00039 [\text{Ft}^2]$   
 $Q = 0.0383 \left[ \frac{\text{Ft}^3}{\text{sec}} \right] = 17.2 \text{ GPM}$

4. PRESSURE TESTING PERMIT - OUTLINE -17-  
FOR VACUUM TEST



Fermilab

Date \_\_\_\_\_

EXHIBIT B  
Pressure Testing Permit\* - OUTLINE

Type of Test: VACUUM  
 Hydrostatic  Pneumatic  
Test Pressure: 14.7 <sup>NEGATIVE</sup> psig Maximum Allowable Working Pressure: 45 psig  
Items to be Tested \_\_\_\_\_

1.8 m KTEV VACUUM WINDOW  
REF. DWG. 9220.832. MD-285394

Location of Test M.A.B. Date and Time \_\_\_\_\_

Hazards Involved RUPTURE OF THE WINDOW COMPONENTS,  
WHAT MAY GENERATE ABNORMAL SOUND LEVEL.  
OTHER HAZARDS RELATE TO TYPICAL INDUSTRIAL INSTALLATION

Safety Precautions Taken  
SEE SUBSECTION 1 OF THIS ELABORATION

Special Conditions or Requirements TESTING PROCEDURE  
HAS TO BE CONSISTENT WITH:  
"KTEV 1.8m VACUUM WINDOW OVERVIEW OF TEST PROCEDURE"

Test Coordinator ANDREW SZYMULANSKI Dept/Date \_\_\_\_\_  
Division/Section Safety Officer \_\_\_\_\_ Dept/Date \_\_\_\_\_  
Division/Section Head \_\_\_\_\_ Dept/Date \_\_\_\_\_

Results \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Witness \_\_\_\_\_ Dept/Date \_\_\_\_\_  
(Safety Officer or Designee)

\* Must be signed by division/section safety officer and division/section head prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.

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5. PRESSURE TESTING PERMIT - OUTLINE FOR HYDROSTATIC TEST

12. 10B



Fermilab

Date \_\_\_\_\_

EXHIBIT B  
Pressure Testing Permit\* - OUTLINE

Type of Test:  Hydrostatic  Pneumatic  
Test Pressure: 45 psig Maximum Allowable Working Pressure: 45 psig  
Items to be Tested 1.8M VACUUM WINDOW  
REF. DWG. 9220.832.MD-285394

Location of Test M.A.B. Date and Time ~  
Hazards Involved FAILURE OF THE TESTED COMPONENTS;  
FLYING DEBRIS

Safety Precautions Taken  
SEE SUBSECTION 1 OF THIS ELABORATION

Special Conditions or Requirements TESTING PROCEDURE HAS TO BE CONSISTENT  
WITH: "KTEV 1.8M VACUUM WINDOW OVERVIEW  
OF TEST PROCEDURE"

Test Coordinator ANDREW SZYMULANSKI Dept/Date \_\_\_\_\_  
Division/Section Safety Officer \_\_\_\_\_ Dept/Date \_\_\_\_\_  
Division/Section Head \_\_\_\_\_ Dept/Date \_\_\_\_\_

Results \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Witness \_\_\_\_\_ Dept/Date \_\_\_\_\_  
(Safety Officer or Designee)

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\* Must be signed by division/section safety officer and division/section head prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.



SUBJECT 1.8 M VACUUM WINDOW  
WINDOW ASSEMBLY HOLDING FIXTURE  
(SPREADER BEAM CAPACITY ANALYSIS)

NAME ANDREW SZYMULANSKI

DATE NOV. 23, 93

REVISION DATA

CHECKED BY: [Signature] 12/22/93

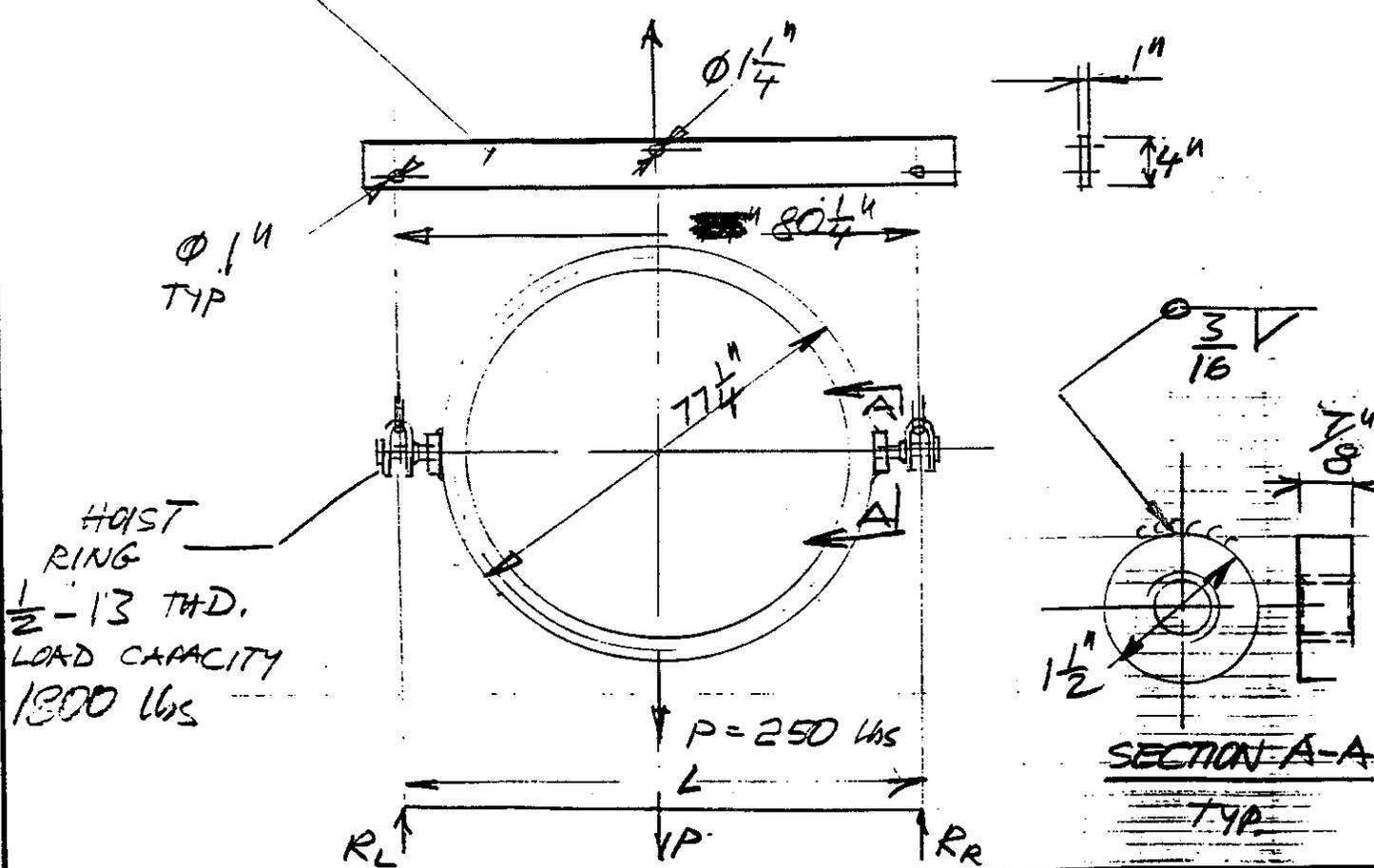
THE FOLLOWING COMPRISE, DESIGN CRITERIA AND STRENGTH ANALYSIS FOR ALUMINUM SPREADED BEAM, WHICH WILL BE USED DURING ASSEMBLY PROCESS OF THE 1.8M VACUUM WINDOW.

GIVEN DATA :

- a) 1.8 M VACUUM WINDOW TEST FIXTURE  
1.8 M WINDOW ASSEMBLY  
DWG. 9220.832.MD-285394 REV.A
- b) WEIGHT OF THE WINDOW ASSEMBLY

$W = 600 \text{ [lbs]}$

ALUMINUM  
T-6061 T6





DETERMINE THE MOMENT OF INERTIA OF THE CROSS SECTION AT THE CENTER OF THE BEAM.

| FIGURE | SIZE     | DISTANCE<br>$\bar{y}$ | $A = b \cdot d$ | $M = A\bar{y}$ | $\bar{I}_y = M\bar{y}$ | $I_g = \frac{bd^3}{12}$ |
|--------|----------|-----------------------|-----------------|----------------|------------------------|-------------------------|
| A      | 1 x 0.75 | 3.625                 | 0.75            | 2.71           | 9.85                   | 0.035                   |
| B      | 1 x 2    | 1                     | 2               | 2              | 2                      | 0.66                    |
| TOTAL  |          |                       | 2.75            | 4.71           | 11.85                  | 0.69                    |

$$\bar{n} = \frac{\sum M}{\sum A} = \frac{4.71}{2.75} = \underline{1.71}$$

$$I_n = I_y + I_g - \frac{M^2}{A}$$

$$I_n = 11.85 + 0.69 - \frac{(4.71)^2}{2.75}$$

$$I_n = 11.85 + 0.69 - 8.06$$

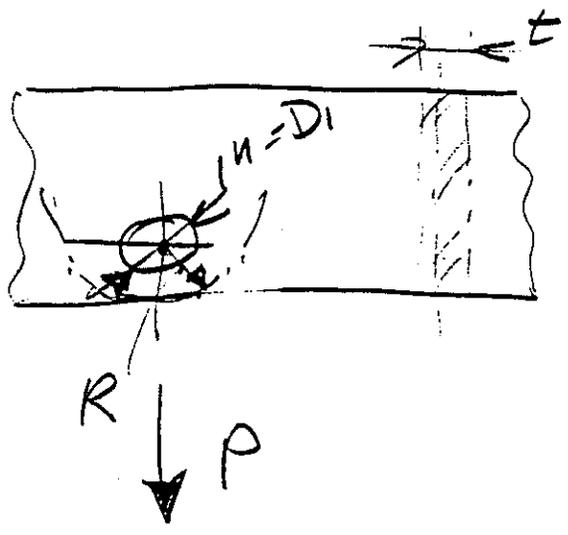
$$I_n = \underline{4.47} \text{ [in}^4\text{]}$$

SECTION MODULUS

$$S_M = \frac{4.47}{2.29} = \underline{1.95} \text{ [in}^3\text{]}$$

|  |         |                 |                 |               |
|--|---------|-----------------|-----------------|---------------|
|  <b>FERMILAB</b><br><b>ENGINEERING NOTE</b> | SECTION | PROJECT<br>KTEU | SERIAL-CATEGORY | PAGE<br>4     |
|  | SUBJECT |                 | NAME            | REVISION DATE |
|  |         |                 | DATE            |               |

CHECKING THE STRESS IN THE BOTTOM PART OF THE BEAM



$$D_1 = 1''$$

$$R = 1.125''$$

$$t = 1''$$

$$S = \frac{42000}{4}$$

$$S = 10,500 \text{ [psi]}$$

$$P = t \left[ 2S \left( R - \frac{D_1}{2} \right) \right] \quad \text{REF. [1]}$$

$$P = 1 \left[ 2(10500) \left( 1.125 - \frac{1}{2} \right) \right]$$

$$P = \underline{13,125 \text{ [lbs]}}$$

UPPER PART OF THE BEAM

$$D_1 = 1.25''$$

$$R = 1.375''$$

$$t = 1$$

$$S = 10500$$

$$P = 1 \left[ 2(10500) \left( 1.375 - \frac{1.25}{2} \right) \right]$$

$$P = \underline{15,750 \text{ [lbs]}}$$

|   |         |                 |                 |             |
|---|---------|-----------------|-----------------|-------------|
|  <b>ENGINEERING NOTE</b> | SECTION | PROJECT<br>KTEV | SERIAL-CATEGORY | PAGE<br>5.  |
|   | SUBJECT |                 | NAME            | REVISION D. |

FIND THE CORRESPONDING MAX. LOAD AT THE CTR. OF THE BEAM

$$\sigma = \frac{M}{S_m} = \frac{PL}{4 \cdot 1.95}$$

$$4(1.95) 10500 = P \cdot L$$

$$P = \frac{81900}{79}$$

$$P = 1036 \text{ [lbs]}$$

SELECTED CAPACITY OF THE BEAM :

600 [lbs]

|   |   |
|---|---|
| ENG. NOTE NO<br><b>62</b>   |   |
|  | LOAD CAPACITY <b>600 lbs</b>  |
|   |  |

WELD

LIFTING ATTACHMENTS (cont.)

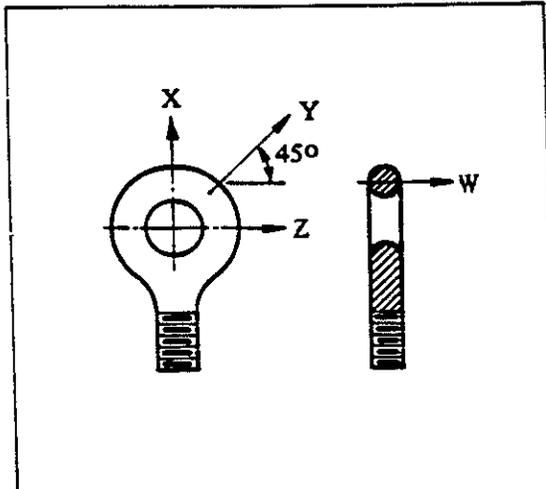
**RECOMMENDED MATERIAL:** A 515-70, A 302 or equivalent. The thickness and length of the lifting lug shall be determined by calculation.

**WELD:** When fillet welds are used, it is recommended that throat areas be at least 50 per cent greater than the cross sectional area of the lug.

To design the lugs the entire load should be assumed to act on one lug.

All possible directions of loading should be considered (during shipment, storage, erection, handling.) When two or more lugs are used for multileg sling, the angle between each leg of the sling and the horizontal should be assumed to be 30 degrees.

EYE - BOLT



Threaded fasteners smaller than 5/8" diameter should not be used for lifting because of the danger of overtightening during assembly.

Commercial eyebolts are supplied with a rated breaking strength in the X direction.

For loadings other than along the axis of the eyebolt, the following ratings are recommended. These are expressed as percentage of the rating in the axial direction.

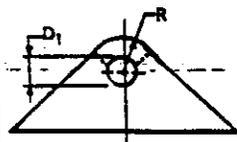
X = 100%    Y = 33%  
Z = 20%    W = 10%

**EXAMPLE:**

An eyebolt of 1 in. diameter which is good for 4960 lb. load in tension (direction x) can carry only 4960 x 0.33 = 1637 lb. load if it acts in direction y.

The above dimensions and recommendations are taken from C. V. Moore: Designing Lifting Attachments, Machine Design, March 18, 1963.

**REF. /** Assuming shear load only thru the minimum section, the required thickness may be calculated by the formula:



$$t = \frac{P}{2S (R - D_1/2)}$$

where  $t$  = required thickness of lug, in.  
 $P$  = load, lbs.  
 $S$  = allowable shear stress, psi.

See page 440 for design of weld and length of lug.

# SPREADER BAR

I.D. N<sup>o</sup> 62

COLOR OF BAR :  
ALUMINUM

LOAD CAPACITY PAINTED  
ON BAR 600 ~~TONS.~~ [LBS]

DATE CAP. & I.D. N<sup>o</sup> PAINTED  
ON BAR DEC. 23, 93

DATE OF LAST LOAD  
TEST. DEC. 23, 93

TEST LOAD WEIGHT 750 <sup>LBS.</sup> [TONS]

TEST LOAD % 125

## STRESS CALCULATIONS:

DONE BY ANDREW SZYMULANSKI

DATE DEC. 23, 93

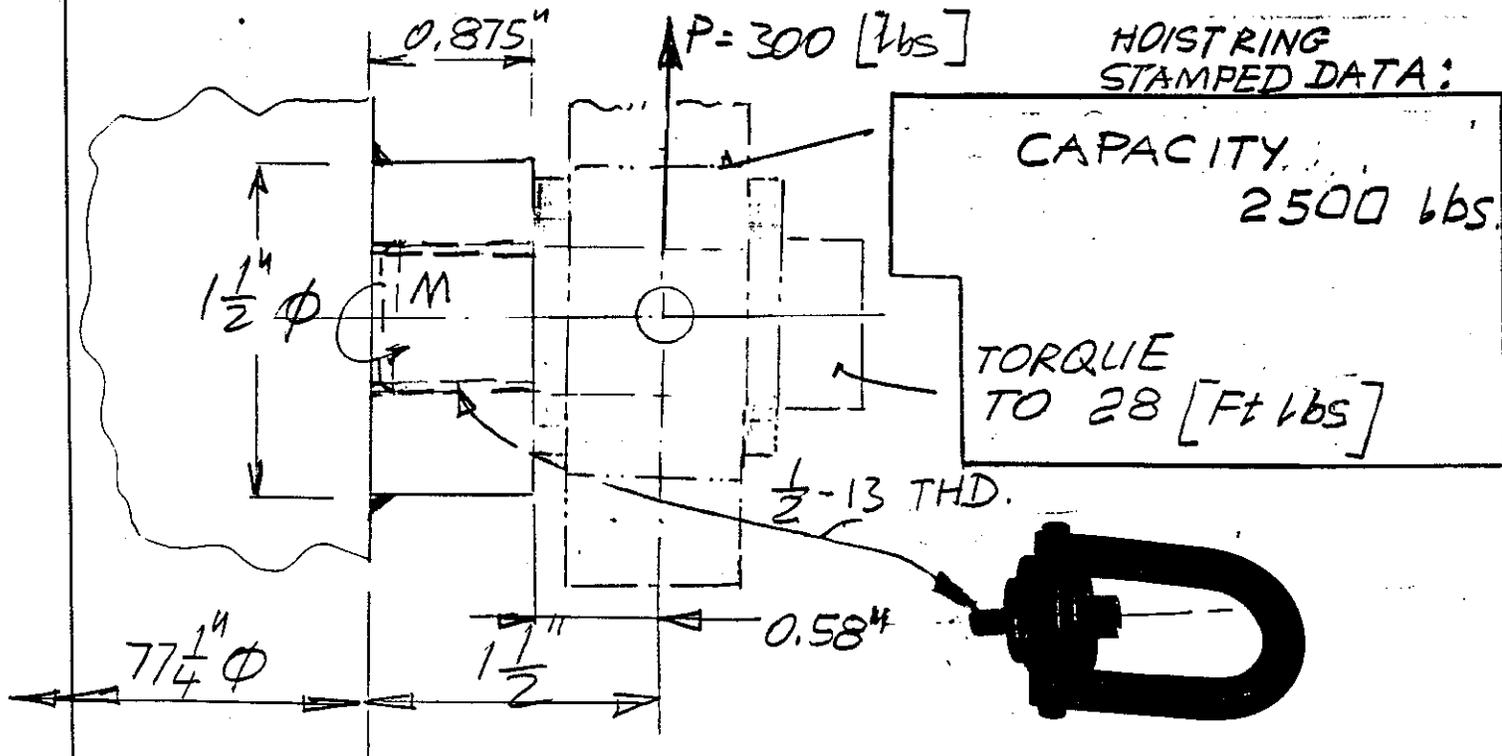
REMARKS :  
ENG. NOTE NO 62  
DWG. NO. PAGE 5 (11A)



SUBJECT 1.8 m VACUUM WINDOW

|               |
|---------------|
| NAME          |
| DATE          |
| REVISION DATE |

7. DETERMINING THE BENDING STRESS IN THE FASTENERS OF A HOIST RINGS AND STRESS IN THE WELDS THAT ATTACH THE THREADED BOSS TO THE FLANGE.



HOISTRING  
STAMPED DATA:  
CAPACITY 2500 lbs  
TORQUE TO 28 [Ft lbs]

1/2-13 THD.

BENDING MOMENT :  $M = P \times (1.5) = 450 \text{ [lb in]}$

MOMENT OF INERTIA OF THE THREADED BOSS.

$$\bar{I} = \frac{\pi}{64} (D^4 - d^4)$$

$$\bar{I} = \frac{\pi}{64} (1.5^4 - 0.5^4)$$

$$\bar{I} = 0.245 \text{ [in}^4\text{]}$$

BENDING STRESS IN THE BOSS

$$\sigma = \frac{M \cdot c}{\bar{I}} = \frac{450 (0.75)}{0.245}$$

$$\sigma = 1377.5 \text{ [psi]}$$



SUBJECT

1.8 M VACUUM WINDOW

NAME

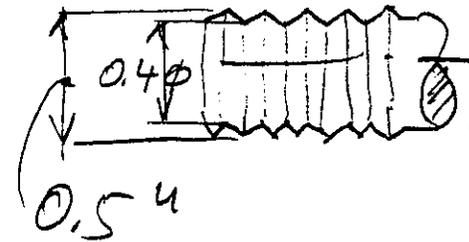
DATE

REVISION DATE

MOMENT OF INERTIA OF THE THREADED FASTENER  
(HOIST RING)

$$I = \frac{\pi d^4}{64} = \frac{\pi (0.4)^4}{64}$$

$$I = 0.00125 \text{ [in}^4\text{]}$$

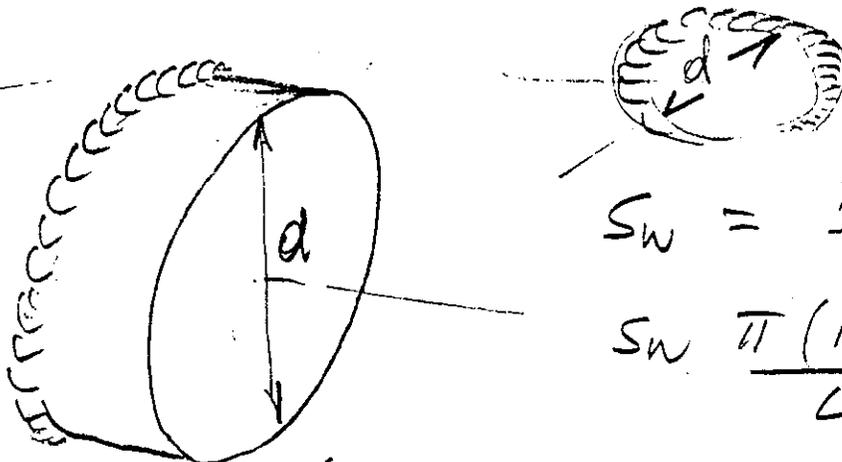


BENDING STRESS IN THE FASTENER

$$\bar{\sigma} = \frac{M_i \cdot C}{I} = \frac{(0.58 \times 300) (0.2)}{0.00125} = 27,840 \text{ [psi]}^*$$

\* THIS IS A ROUGH CHECK TO VERIFY MANUFACTURER RATING DATA OF THE HOIST RING.

FIND PROPERTIES OF WELD, TREATING IT AS A LINE



$$S_w = \frac{\pi d^2}{4} \quad [\text{REF.}]$$

$$S_w = \frac{\pi (1.5)^2}{4} = 1.76 \text{ [in}^2\text{]}$$

(SEE ATTACHED REFERENCE INFORMATION ON FOLLOWING PAGES; 21B, 22B, 23B.)



SUBJECT

1.8 M VACUUM WINDOW

NAME

DATE

REVISION DATE

$$A_w = \pi d = \pi (1.5) = 4.71 \text{ [in]}$$

BENDING FORCE ON WELD :

$$f_b = \frac{M}{S_w} = \frac{450}{1.76}$$

$$f_b = 255.7 \text{ [lbs/in]}$$

VERTICAL SHEAR ON THE WELD

$$f_v = \frac{V}{A_w} = \frac{P}{A_w} = \frac{300}{4.71} = 63.7 \text{ [lbs/in]}$$

ACTUAL RESULTANT FORCE ON THE WELD :

$$f_r = \sqrt{f_b^2 + f_v^2}$$

$$f_r = 263.5 \text{ [lbs/in]}$$

FIND THE SIZE OF A FILLET WELD :

$$w = \frac{\text{ACTUAL FORCE}}{\text{ALLOWABLE FORCE}}$$

$$= \frac{263.5}{9600} = 0.0274$$

WE ARE USING  $\frac{3}{16}$  

REF. [2] (3) FOLLOWING PAGES  
24E  
23

TABLE 2 - MINIMUM WELD SIZES FOR THICK PLATES (AWS)

| THICKNESS OF THICKER PLATE JOINED<br>$t$ | MINIMUM LEG SIZE OF FILLET WELD<br>$w$ |
|--|--|
| to 1/2" incl.                            | 3/16"                                  |
| over 1/2" thru 3/4"                      | 1/4"                                   |
| over 3/4" thru 1 1/2"                    | 5/16"                                  |
| over 1 1/2" thru 2 1/4"                  | 3/8"                                   |
| over 2 1/4" thru 6"                      | 1/2"                                   |
| over 6"                                  | 5/8"                                   |

Minimum leg size need not exceed thickness of the thinner plate.

Table 1 gives the leg size of fillet welds for various plate thicknesses, based on formulas #1 and #2. Values have been adjusted where necessary to comply with AWS-recommended minimums for thick plates (Table 2).

For rigidity designs, the fillet weld may be reduced by using intermittent welds.

Thick Plates

The American Welding Society recognizes that thick plates offer greater restraint, and produce a faster cooling rate for the welds. As a result they recommend the minimum fillet weld sizes in Table 2 for various plate thicknesses, based on the thicker plate.

This table is predicated on the theory that the required minimum weld size will provide sufficient welding heat input into the plate to give the desired slow rate of cooling.

This is not a complete answer to this problem; for example, a plate thicker than 6" would require a minimum weld size of 3/8", yet in actual practice this would be made in several passes. Each pass would be equivalent to about a 3/16" fillet, and have the heat input of approximately a 3/16" weld which may not be sufficient unless the plates are preheated.

A partial solution to this problem would be the following: Since the first pass of the joint is the most critical, it should be made with low-hydrogen electrodes and a rather slow travel speed. Resulting superior weld physicals, weld contour, and maximum heat input provide a good strong root bead.

3. TYPES OF WELDS

a. Primary welds transfer the entire load at the particular point where they are located. If the weld fails, the member fails. The weld must have the same property as the member at this point. In brief, the weld becomes the member at this point.

b. Secondary welds simply hold the parts to-

gether, thus forming the member. In most cases, the forces on these welds are low.

c. Parallel welds have forces applied parallel to their axis. In the case of fillet welds, the throat is stressed only in shear. For an equal-legged fillet, the maximum shear stress occurs on the 45° throat.

d. Transverse welds have forces applied transversely or at right angles to their axis. In the case of fillet welds, the throat is stressed in both shear and normal (in tension or compression). For an equal-legged fillet weld, the maximum shear stress occurs on the 67½° throat, and the maximum normal stress occurs on the 22½° throat.

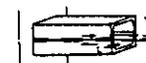
4. SIMPLE TENSILE, COMPRESSIVE OR SHEAR LOADS ON WELDS

For a simple tensile, compressive or shear load, the given load is divided by the length of the weld to arrive at the applied unit force, lbs per linear inch of weld. From this force, the proper leg size of fillet weld or throat of groove weld may be found.

5. BENDING OR TWISTING LOADS ON WELDS

The problem here is to determine the properties of the welded connection in order to check the stress in the weld without first knowing its leg size. Some design texts suggest assuming a certain weld-leg size and then calculating the stress in the weld to see if it is overstressed or understressed. If the result is too far off, then the weld-leg size is readjusted.

TABLE 3 - DETERMINING FORCE ON WELD

| Type of Loading  | standard design formula    | treating the weld as a line |
|--|----------------------------|-----------------------------|
|  | stress lbs/in <sup>2</sup> | force lbs/in                |
| PRIMARY WELDS<br>transmit entire load at this point                                  |                            |                             |
|  | $\sigma = \frac{P}{A}$     | $f = \frac{P}{A_w}$         |
|  | $\sigma = \frac{V}{A}$     | $f = \frac{V}{A_w}$         |
|  | $\sigma = \frac{M}{S}$     | $f = \frac{M}{S_w}$         |
|  | $\tau = \frac{T C}{J}$     | $f = \frac{T C}{J_w}$       |
| SECONDARY WELDS<br>hold section together - low stress                                |                            |                             |
|  | $\tau = \frac{V a y}{I t}$ | $f = \frac{V a y}{I n}$     |
|  | $\tau = \frac{T}{2At}$     | $f = \frac{T}{2A}$          |

A = area contained within median line.  
(\* ) applies to closed tubular section only.

This has the following disadvantages:

1. Some decision must be made as to what throat section is going to be used to determine the property of the weld. Usually some objection can be raised to any throat section chosen.

2. The resulting stresses must be combined and, for several types of loading, this can be rather complicated.

In contrast, the following is a simple method to determine the correct amount of welding required for adequate strength. This is a method in which the weld is treated as a line, having no area, but a definite length and outline. This method has the following advantages:

1. It is not necessary to consider throat areas because only a line is considered.

2. Properties of the welded connection are easily found from a table without knowing weld-leg size.

3. Forces are considered on a unit length of weld instead of stresses, thus eliminating the knotty problem of combining stresses.

4. It is true that the stress distribution within a fillet weld is complex, due to eccentricity of the applied force, shape of the fillet, notch effect of the root, etc.; however, these same conditions exist in the actual fillet welds tested and have been recorded as a unit force per unit length of weld.

### 6. DETERMINING FORCE ON WELD

Visualize the welded connection as a single line, having the same outline as the connection, but no cross-sectional area. Notice, Figure 1, that the area ( $A_w$ ) of the welded connection now becomes just the length of the weld.

Instead of trying to determine the stress on the weld (this cannot be done unless the weld size is known), the problem becomes a much simpler one

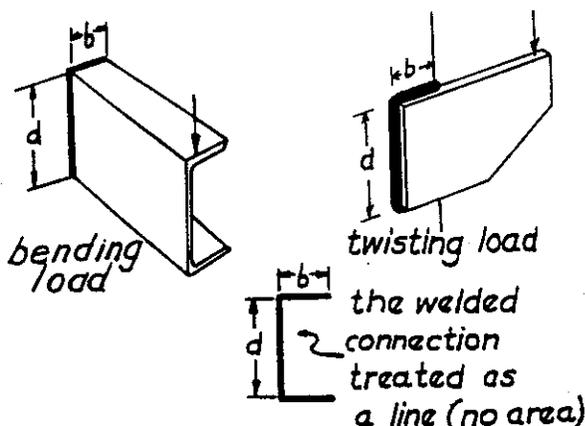


Fig. 1 Treating weld as a line.

TABLE 4 - PROPERTIES OF WELD TREATED AS LINE

| Outline of Welded Joint<br>b=width<br>d=depth | Bending<br>(about horizontal axis x-x)   | Twisting  |
|---|--|---|
|   | $S_w = \frac{d^2}{6} \text{ in.}^2$  | $J_w = \frac{d^3}{12} \text{ in.}^3$                          |
|   | $S_w = \frac{d^2}{3}$  | $J_w = \frac{d(3b^2 + d^2)}{6}$                               |
|   | $S_w = bd$   | $J_w = \frac{b^3 + 3bd^2}{6}$                                 |
|   | $S_w = \frac{4bd + d^2}{6} \cdot \frac{d^2(4b + d)}{3(2b + d)}$<br>top bottom                                    | $J_w = \frac{(b + d)^3 - b^2d^2}{12(b + d)}$                  |
|   | $S_w = bd + \frac{d^2}{6}$   | $J_w = \frac{(2b + d)^3}{12} - \frac{b^2(b + d)^2}{(2b + d)}$ |
|   | $S_w = \frac{2bd + d^2}{3} \cdot \frac{d^2(2b + d)}{3(b + d)}$<br>top bottom                                     | $J_w = \frac{(b + 2d)^3}{12} - \frac{d^2(b + d)^2}{(b + 2d)}$ |
|   | $S_w = bd + \frac{d^2}{3}$   | $J_w = \frac{(b + d)^3}{6}$                                   |
|   | $S_w = \frac{2bd + d^2}{3} \cdot \frac{d^2(2b + d)}{3(b + d)}$<br>top bottom                                     | $J_w = \frac{(b + 2d)^3}{12} - \frac{d^2(b + d)^2}{(b + 2d)}$ |
|   | $S_w = \frac{4bd + d^2}{6} \cdot \frac{4bd^2 + d^3}{6b + 3d}$<br>top bottom                                      | $J_w = \frac{d^3(4b + d)}{6(b + d)} + \frac{b^3}{6}$          |
|   | $S_w = bd + \frac{d^2}{3}$   | $J_w = \frac{b^3 + 3bd^2 + d^3}{6}$                           |
|   | $S_w = 2bd + \frac{d^2}{3}$  | $J_w = \frac{2b^3 + 6bd^2 + d^3}{6}$                          |
|   | $S_w = \frac{\pi d^2}{4}$  | $J_w = \frac{\pi d^4}{4}$                                     |
|   | $I_w = \frac{\pi d}{2} (D^4 + \frac{d^4}{2})$<br>$S_w = \frac{I_w}{c}$<br>where $c = \frac{\sqrt{D^2 + d^2}}{2}$ |   |

of determining the force on the weld.

By inserting the property of the welded connection treated as a line into the standard design formula used for that particular type of load (see Table 3), the force on the weld may be found in terms of lbs per linear inch of weld.

Example: Bending

| Standard design formula<br>(bending stress)                             | Same formula used for weld<br>(treating weld as a line)           |
|---|---|
| $\sigma = \frac{M}{S} = \frac{\text{lbs}}{\text{in.}^2} \text{ stress}$ | $f = \frac{M}{S_w} = \frac{\text{lbs}}{\text{in.}} \text{ force}$ |

Normally the use of these standard design formulas results in a unit stress, psi; however, when the weld is treated as a line, these formulas result in a force on the weld, lbs per linear inch.

For secondary welds, the weld is not treated as a line, but standard design formulas are used to find the force on the weld, lbs per linear inch.

In problems involving bending or twisting loads Table 4 is used to determine properties of the weld

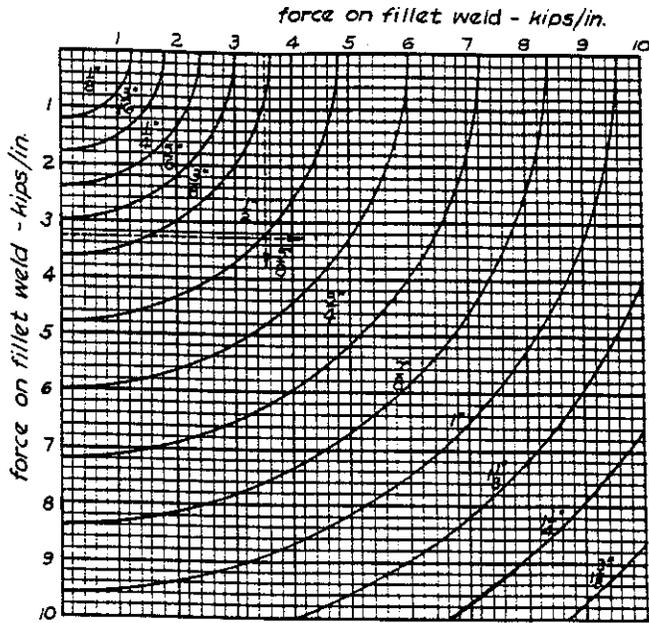


Fig. 2 Fillet weld leg size for combined forces.

treated as a line. It contains the section modulus ( $S_w$ ), for bending, and polar moment of inertia ( $J_w$ ), for twisting, of some 13 typical welded connections with the weld treated as a line.

For any given connection, two dimensions are needed, width (b) and depth (d).

Section modulus ( $S_w$ ) is used for welds subject to bending loads, and polar moment of inertia ( $J_w$ ) for twisting loads.

Section moduli ( $S_w$ ) from these formulas are for maximum force at the top as well as the bottom

portions of the welded connections. For the unsymmetrical connections shown in this table, maximum bending force is at the bottom.

If there is more than one force applied to the weld, these are found and combined. All forces which are combined (vectorially added) must occur at the same position in the welded joint.

Determining Weld Size by Using Allowables

Weld size is obtained by dividing the resulting force on the weld found above, by the allowable strength of the particular type of weld used (fillet or groove), obtained from Table 5 (steady loads) or Table 6 (fatigue loads).

For a joint which has only a transverse load applied to the weld (either fillet or groove weld), the allowable transverse load may be used from the table. If part of the load is applied parallel (even if there are transverse loads in addition), the allowable parallel load which is lower must be used.

If there are two forces at right angles to each other, the resultant is equal to the square root of the sum of the squares of these two forces.

$$f_r = \sqrt{f_1^2 + f_2^2} \dots\dots\dots (3)$$

If there are three forces, each at right angles to each other, the resultant is equal to the square root of the sum of the squares of the three forces.

$$f_r = \sqrt{f_1^2 + f_2^2 + f_3^2} \dots\dots\dots (4)$$

The chart in Figure 2 can be used for E60 welds to combine two forces and indicate the proper fillet-weld leg size.

| Fillet Weld<br>(For 1" weld leg)    | Groove weld<br>(for 1" weld thickness)               | Partial Penetration **<br>Groove weld*<br>(For 1" weld thickness) |
|-------------------------------------|--|---|
| Parallel Load                       |  |   |
| E60 or SAW - 1 weld<br>9600 (AWS)   | $\tau = .40 \sigma$ of base metal<br>(shear) (AWS)   | E60 or SAW - 1 weld<br>13,600 (AISC)                              |
| E70 or SAW - 2 weld<br>11,200 (AWS) |  | E70 or SAW - 2 weld<br>15,800 (AISC)                              |
| Transverse Load                     |  |   |
| E60 or SAW - 1 weld<br>11,200       | $\tau = .60 \sigma$ of base metal<br>(tension) (AWS) | E60 or SAW - 1 weld<br>13,600 (AISC)                              |
| E70 or SAW - 2 weld<br>13,100       |  | E70 or SAW - 2 weld<br>15,800 (AISC)                              |

TABLE 5 - ALLOWABLE STEADY LOADS (lbs/linear in. of weld)

\*\* tension transverse to axis of weld or shear - use table for tension parallel to axis of weld or compression - weld same as plate

\*For bevel joint, deduct first 1/8" for effective throat, if done by manual electrode.

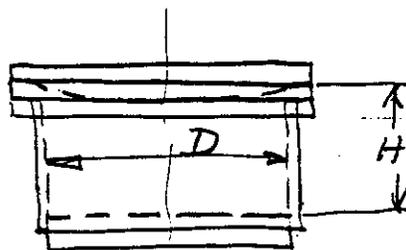
8. DETERMINE AN APPROXIMATE AIR IMPACT DISCHARGE, DURING UNCONTROLLED RUPTURE OF THE KEVLAR FABRIC AT FULL VACUUM CASE.

VOLUME OF THE VACUUM SPACE.

$$V = \frac{\pi D^2}{4} \cdot H$$

$$V = \frac{\pi (5.91)^2}{4} \cdot 1.12$$

$$V = \underline{30.72 \text{ [Ft}^3\text{]}}$$



$$D = 5.91 \text{ Ft}$$

$$H = 1.12 \text{ Ft}$$

EQUIVALENT OF STORED ENERGY IN THE VOLUME "V" AT  $p = 14.7 \text{ psi}$

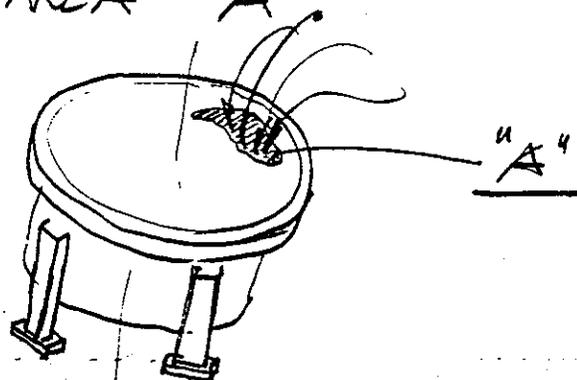
$$E = p \cdot V$$

$$E = 14.7 (144) (30.72) \frac{\text{lbs}}{\text{Ft}^2} \text{ Ft}^3 \text{ [lbs Ft]}$$

$$E = \underline{65,028.}$$

THIS POTENTIAL ENERGY OF THE AIR ABOVE THE KEVLAR WINDOW, WILL CONVERT TO KINETIC ENERGY OF AIR MOLECULES FLOWING THROUGH

A RUPTURE OF AN AREA "A"



$$E = E_k$$

$$E_k = \frac{m \cdot V^2}{2}$$

FROM CONTINUITY FLOW :

$$Q = A \cdot V$$

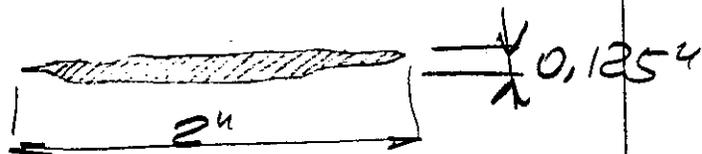
WHERE

$V$  - VELOCITY OF  
AIR AT  
RUPTURE " $A$ "

$A$  - RUPTURE AREA

$$E_k = \frac{m \left( \frac{Q}{A} \right)^2}{2}$$

ASSUMED " $A$ " :



$$A = \underline{0.0017} \text{ Ft}^2$$

$$E_k = \frac{m Q^2}{2 A^2}$$

$m$  - MASS OF THE AIR

$$m = \frac{0.08 (30.72)}{32.2}$$

0.08 - SPECIFIC  
WEIGHT OF AIR

$$m = \underline{0.076} \left[ \frac{\text{lbs sec}^2}{\text{ft}} \right]$$

$$\left[ \frac{\text{lbs}}{\text{ft}^3} \right]$$

$$E_k = \frac{0.076 Q^2}{2 (0.0017)^2}$$

$$65028 = \frac{0.076 Q^2}{2 (0.0017)^2}$$

$$Q^2 = 4.94$$

$$Q = 2.22 \left[ \frac{ft^3}{sec} \right]$$

$$Q' = 2.22 (0.08)$$

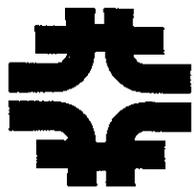
$$Q' = \underline{0.17} \left[ \frac{lbs}{sec} \right]$$

THIS IS A MARGINAL IMPACT ON  
THE FIXTURE ASSEMBLY WHICH  
WEIGHT IS 4250 [lbs].

~~26 B.~~  
28.

(23)

27-B1  
29



Fermilab

Draft Revision March 4, 1994

# E-832 K-Tev 1.8 Meter Window Assembly Procedure

Written by Dave Erickson  
January 15, 1994

SEE APPENDIX 5  
FOR FINAL  
VERSION

## Materials, Equipment, and References

- Drawing 9220.832.MD-285394 ... Window Assembly
- Drawing 922.0832.MD-285391 ... Vessel Assembly
- Aluminum spreader bar (I.D. 62 600 lb. capacity)
- .250 Diameter Urethane O-ring stock
- .250 Diameter 1100 Series Aluminum wire stock
- .005 X 72" DuPont Mylar Sheet (Aluminized coating)  
MSDS#12407
- Woven Kevlar MSDS# 12406
- Hysol epoxy ... 826 resin (MSDS# 07625 )and 308 Hardener (MSDS# 06160 )
- RTV 157 (gray) MSDS#04471
- Utility knife and razor blades
- Surgical knife and blades
- Wooden tongue depressors
- Oxy-Acet unit with standard regulators, hoses and tips.

- Nederman electrostatic filter for exhausting fumes when burning Kevlar and Mylar. Flexible extension hose for the output side of the filter unit.
- 600 ft/lb. torque wrench
- Removable wooden flange periphery work surface
- Removable aluminum cover to protect assembly when not worked on
- Nylon blocks to elevate upstream flange from Test Vessel
- 2 inch wide green tape stock # 1365-0980
- Curved surgical scissors
- Kevlar scissors
- Test Vessel is used as an assembly table when making window
- Eye protection (Maybe particle mask)
- ES&H requirements/recommendations

## Preparatory Work

First and foremost, care must be taken to ensure a clean and accident free environment.

### 1100 Aluminum Alloy O-ring

One 1100 aluminum alloy o-ring (.250 diameter) must be made for window. Determine the correct length of the 1100 aluminum rod needed for o-ring groove by fitting the rod into the appropriate o-ring groove in the flange. Determine the correct groove by consulting the assembly print (MD-285394). Cut the rod to the correct length and weld the two ends together. File and sand the o-ring weld until it blends with the parent material diameter. There should not be any scratches or nicks in the o-ring. Hand polish the o-ring using a Scotchbrite pad. Store ring in a safe place until needed.

### Urethane O-ring

One o-ring (.250 diameter) is needed for window flange. Determine the length of urethane o-ring chord material by fitting material in the correct o-ring groove (again consult assembly print for correct groove). Cut the o-ring material to length and join the ends using the conventional heat method. Trim excess material carefully with razor blade to blend with rest of chord. Clean thoroughly and store in a safe place until needed.

.005 Mylar (Polyester metallized film)

Unroll and inspect mylar to be sure there are no scratches, nicks or other defects. Cut two pieces of mylar approximately six inches larger than flange. This will ensure the mylar sheet is large enough to be pulled taut over the flange and then taped to the work table/shelf. Orientation of the metallized surface is critical. It should be the atmospheric side of the window. Double check the assembly drawing.

**Kevlar**

Unroll and discard the outer layer of kevlar if signs of degradation are obvious. Inspect the kevlar material to be sure that there are no cuts, punctures or strands that have been pulled in the woven material. Cut the kevlar so it is six inches larger in diameter than the flange. This will ensure the kevlar sheet is large enough to be pulled taut over the flange and then taped to the outrigger.

**Epoxy**

The epoxy should not be prepared until it is going to be used. A one to one mixing ration is used. Mix 75 ml. of hardener to 75 ml. of 826 resin. Mix thoroughly and put into a squeeze bottle. This mixture will fully cure in 24 hours.

**Wooden Outrigger Platform (Flange work table)**

The wooden outriggers (table) are made of 3/4" thick plywood. Special brackets that support the plywood were used to align 8 nuts which were welded to the flange (9220.832.MD-285389) equally spaced around flange diameter. The nuts were welded in a position that made approximately 12 inches larger than the diameter of the window flange. This will aid in taping of mylar and kevlar during assembly. The outrigger is made to be removable for further assembly or to make a new window. Nuts will remain on flange indefinitely.

# Assembly Procedure

(most of this procedure requires two people)

1. Screw 1/2" - 13 swivel eye bolts into special removable pick points of upstream flange MD-285389. Using crane and spreader bar, place the flange (o-ring side up) onto the equally spaced nylon standoffs which have been placed on test vessel flange.
2. Attach wooden outrigger platform to upstream flange (MD-285389).

3. Center one piece of .005 mylar (aluminized side down) over the flange and onto the outrigger platform. Tape the mylar to the outrigger platform as needed allowing the mylar to sag 1/4 inch in the middle of the flange. Use straight edge to measure sag.
4. Lay the Kevlar over the mylar, making sure it is smoothed out evenly on the mylar. Tape kevlar down onto outrigger platform all the way around. Check with a straight edge to ensure 1/4 inch sag.
5. Place and then tape the second piece of mylar (aluminized side up) on top of the kevlar so it conforms to the first piece of mylar and kevlar, maintaining the 1/4 inch sag in the middle of the flange. Again tape down mylar as needed to platform.
6. Using crane and spreader bar, lift downstream flange (MD-285390) over upstream flange (MD-285389) with the o-ring facing down. Lower it carefully until it is almost touching flange (MD-285389). Shine a flashlight up through four holes 90 degrees apart in flange. When the holes are lined up between both flanges, lower flange (MD-285390) onto upstream flange (MD-285389).
7. Make timing marks on the top flange (MD-285390), the window, and the bottom flange (MD-285389). These marks will be used to align the flanges and the window later on.
8. Locate the four holes 90 degrees apart which will become the bolt hole clearance holes. Use torch to carefully burn the window material from the inside of the bolt clearance holes. **You must use the electrostatic filter when burning any kevlar and mylar!**  
\*Extreme care must be taken to avoid snagging or pulling a strand of kevlar.
9. The electrostatic filter must be exhausted outside of the assembly building. After the four clearance holes have been burned out, temporarily place bolts through the holes in the assembly. Tighten the bolts down to 80 foot/pounds. This will hold flanges while burning the window material out of the remaining holes. **Remember to use the electrostatic filter exhaust.**
10. Using torch set, burn the material out of the remaining bolt holes. Be sure to remove all kevlar strands from the holes. If they are not removed, the strands may catch on the bolts when they are screwed in.
11. When all the bolt holes are open, remove the four bolts which were temporarily placed in the holes.

12. Using the crane carefully lift the top flange (MD-285390) off the lower flange (MD-285389), making sure the window material does not stick to the flange while it is removed. Use tongue depressors to separate material from flange. Flip flange over 180 degrees so o-ring is facing up. Place flange in work area so that aluminum o-ring can be installed.
13. Carefully peel the top sheet of mylar away from the kevlar by feeding wooden tongue depressors between the two materials in the areas where the holes have been burned away. Once again, care must be taken to ensure that the kevlar strands are not pulled. After the mylar is completely separated from the kevlar, place the mylar in a safe place until it is needed again.
14. The orange o-ring must be inserted into the o-ring groove of the upstream flange (MD-285389). Coat lightly the orange o-ring with vacuum silicone grease. From under the flange (between the test vessel flange and nylon standoffs) carefully squeeze the o-ring between the mylar and the flange until it snaps into the o-ring groove of the flange (MD-285389).
15. When the orange o-ring is in place, it will create a small impression on the surface of the kevlar. Use a felt tip marker to accentuate this ridge around the kevlar. This marker line will act as a guide for applying the epoxy.
16. Working on the downstream flange (MD-285390), which was previously removed from the upstream flange (MD-285389), apply spots of RTV silicone in the bottom of the aluminum o-ring groove. Insert the aluminum o-ring into the flange o-ring groove. Allow the RTV to set up, which usually takes about three hours. The RTV will hold the aluminum o-ring in place when the flange is picked up, flipped over and put back onto the upstream flange (MD-285389).
17. While the RTV is setting up, mix the epoxy and apply a bead of epoxy to the marker line on the kevlar. Use a wooden tongue depressor to work the epoxy into the kevlar. The epoxy will soak into the kevlar and spread out about 3/4 of an inch.
18. Carefully place the mylar which was removed in Step 13, back on the top of the kevlar, lining up the timing marks.
19. Using the crane and the spreader bar lift and turn over the downstream flange (MD-285390) with the aluminum o-ring. Slowly lower the flange with the aluminum o-ring facing down, lining up the timing marks on the upper flange the window and the

lower flange. Use bolt holes as a guide when lowering flange. Lower the flange completely so it is sitting on flange (MD-285389).

- 20. Screw bolts through top flange (MD-28390) into lower flange (MD-285389) and torque bolts using bolt tighten sequence provided on the print.
- 21. After curing the epoxy for 24 hours, the excess window material on the outside of the flanges can be cut away with a scissors using the outside edge of the flanges as a guide. The remaining material can be burned away with a torch. Remember to use the smoke eater when burning the material.
- 22. Remove the outrigger platform from the assembly.
- 23. Before leak checking the window assembly, the mylar window on the vacuum side must be cut out (it was used as an assembly aid). You must carefully flip the assembly over 180 degrees. Extreme care must be taken when cutting this mylar window out because the mylar is laying next to the kevlar. With the vacuum side up, lift the center of the mylar with a piece of tape which has been stuck on the surface in the middle of the mylar window. When the mylar has been lifted away from the kevlar, carefully cut a small slit using a hooked surgical knife. Using the slit to access the mylar, carefully use blunt nose scissors to cut around the mylar window to with in an inch or an inch and one half of the inner wall of the flange. Remove mylar cutout and dispose of.
- 24. The assembly is now ready for vacuum testing. See comments before continuing.

COMMENTS :

This procedure was derived from previous kevlar-mylar window assembly procedures. Reference : E-773/731 12 inch and 30 inch and 48 inch diameter windows. Drawings: #9220.731-MD-202185 and 9220.731-MD-202178. This procedure is still in draft form pending Safety Review Committee approval.

The vacuum, hydrostatic, and puncture tests that follow the completion of the window assembly fall under a procedure written by Andrew Szymulanski. He is coordinating this with the Safety Review Committee. The ordered tests shall not be executed until A. Szymulanski has the Safety Review Committee approval to do so.

\* The RD/ES&H section (Bill Nicholson) is reviewing personnel hazards having to do with the burning of the kevlar and mylar. However, the accepted and applicable procedure is to exhaust the output side of the fume collecting apparatus (electrostatic filter) to the outside of the assembly building. Extending the exhaust through a door or window with a flexible exhaust extension is acceptable.

DRAFT

10. REQUIRED TORQUE AND BOLTING SEQUENCE

A SERIES OF TESTS HAS BEEN PERFORMED, TO FIND THE RIGHT CLAMPING FORCE FOR THE KEVLAR / MYLAR SANDWICH. THE TORQUE VALUE WHICH YIELDED THE MAX. PULL OUT FORCE FOR THE CLAMPED MATERIAL WAS 250 Ft lbs.

THIS VALUE TRANSLATES TO 45970 [psi] TENSILE STRENGTH IN THE BOLT.

THE MAX. STRENGTH OF THE BOLT IS 153000 [psi]

10.1 TIGHTENING THE BOLTS.

SKETCH NO 2 SHOWS THE WINDOWV ASSEMBLY BOLT ARRANGEMENT.

10.1.1 START WITH BOLT NO 1 POSITION (1a) AND TIGHTEN THE FIRST (4) BOLTS TO 25 Ft lbs AS FOLLOXV :

1a, 1b, 1c, 1d

10.1.2 CONTINUE WITH THE NEXT (4) BOLTS IN THE SAME MANNER, FOLLOWING THE ARROW DIRECTION.

10.1.3 CONTINUE OTHER (4) AS ABOVE UNTIL ALL ARE TIGHTENED.

10.1.4 INCREASE THE TORQUE TO 50 [Ft lbs] AND CONTINUE AS IN:

- 4.1.1
- 4.1.2
- 4.1.3

10.1.5 INCREASE TORQUE VALUES

|      |     |          |
|------|-----|----------|
| TO : | 100 | [Ft lbs] |
|      | 150 | -  -     |
|      | 200 | -  -     |
|      | 250 | -  -     |

FOLLOWING THE STEPS OF

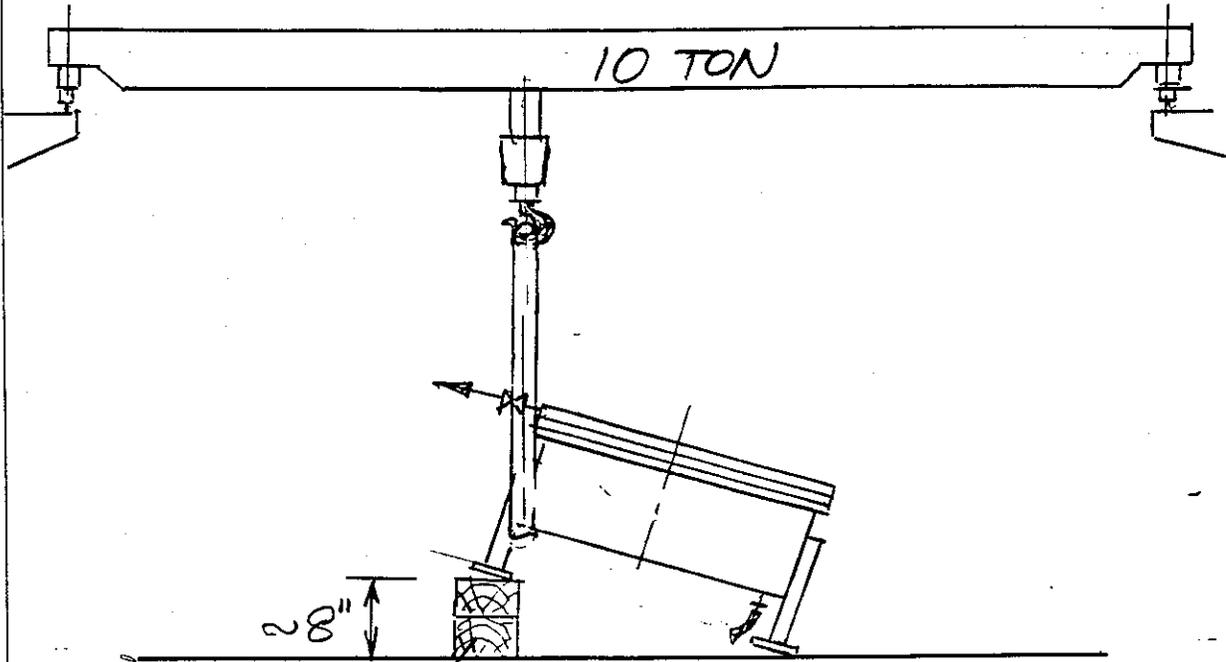
- 4.1.1
- 4.1.2
- 4.1.3

FOR EACH TORQUE VALUE.

10.2 PLACE THE WINDOW ASSEMBLY ON THE VESSEL FLANGE, AND INSTALL THE BOLTS (POS. 2.) AND NUTS (POS. 3) WITH SPRING WASHERS.

TIGHTEN ALL (60) BOLTS IN THE SAME WAY AS DESCRIBED FOR POS. 1 BOLTS,

RIGGING ARRANGEMENT FOR AN AIR BLEEDING OPERATION.



72" LG. - (4" x 4" NOMINAL) 2 PCS.

CRANE WILL STAY ATTACHED AND LOCKED OFF DURING THE BLEEDING OPERATION

SKETCH 3

## APPENDIX

SELECTING THE  
RELIEF VALVE :

MANUFACTURER: TELEDYNE FARRIS ENG.  
CATALOG : 189 C

VALVE TYPE  
NUMBER : 1850

INLET  
MNPT  $1/4$ "

OUTLET  
FNPT  $1/2$ "

MAX. SET  
PRESSURE  
RATING : 300 psig

CAPACITY OF THE VALVE @ 25% OVERPRESSURE  
AND SET PRESSURE OF 40 psig  
(SEE CAPACITIES TABLE ON PAGE 6  
OF "FARRIS" CAT. 189 C.)

CAPACITY = 30 GAL/min

CAPACITY @ 10% OVERPRESSURE :

$$\text{CAP. (@10\%)} = 30 \times 0.6 = 18 \text{ GAL/min}$$

SET PRESSURE + 10% OVERPRESSURE =

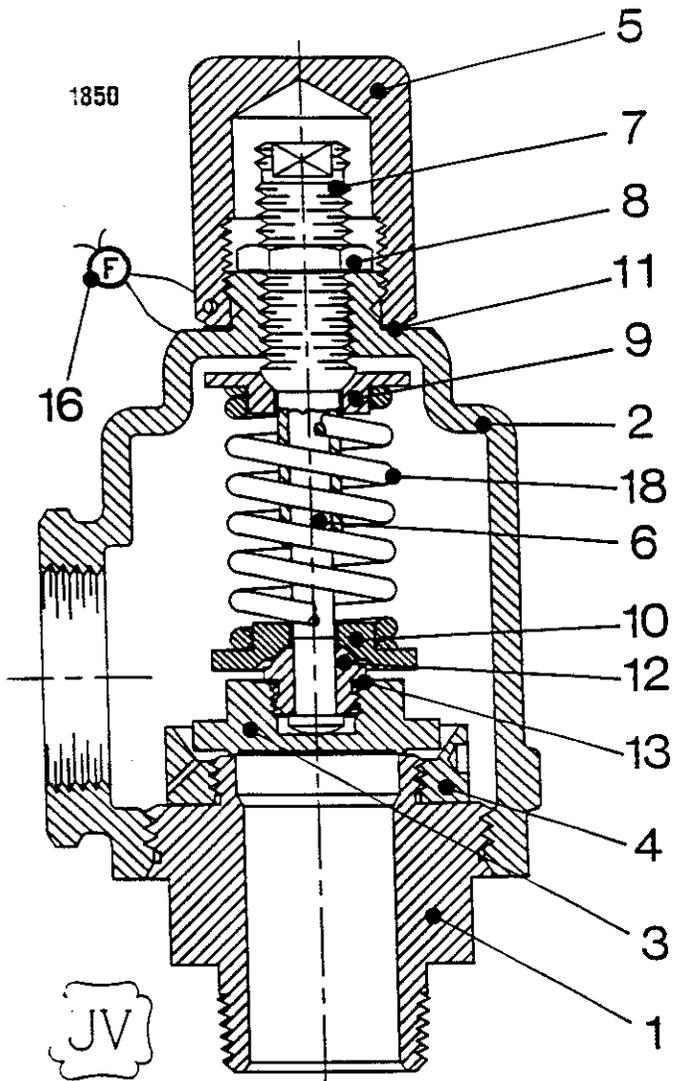
MAX. PRESSURE INSIDE  
THE VESSEL

$$40 + 4 = 44$$

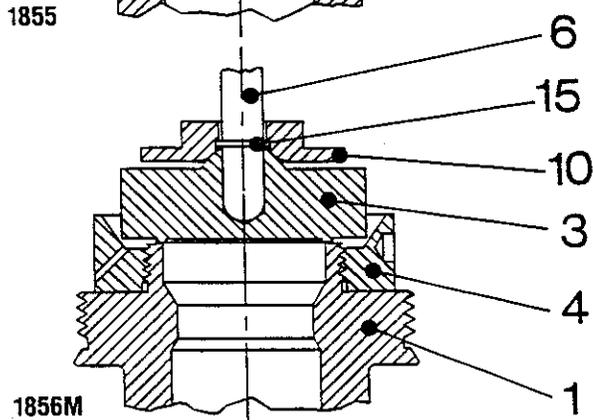
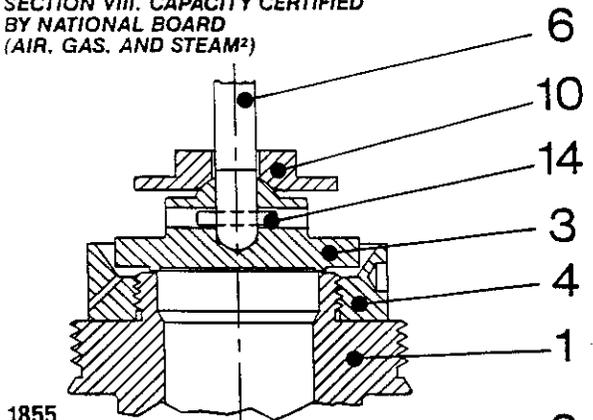
$$44 < 45$$

WHERE 45 PERTAINS TO MAX. ALLOWABLE  
PRESSURE INSIDE THE VESSEL

# SERIES 1850, 1855 & 1856M PRESSURE RELIEF VALVES



BUILT IN CONFORMANCE TO ASME CODE SECTION VIII. CAPACITY CERTIFIED BY NATIONAL BOARD (AIR, GAS, AND STEAM?)



## BILL OF MATERIALS

| Item No. | Part Name                   | Material  |   |  |  |
|----------|-----------------------------|---|---|--|--|
|          |                             | 1850, 1850H, 1852, 1852H                            | 1850/S4, 1850H/S4, 1852/S4, 1852H/S4                | 1855                                   | 1856M                                  |
| 1        | Body                        | SA-479 Type 316 St. St. Or SA-351. Gr. CF8M St. St. | SA-479 Type 316 St. St. Or SA-351. Gr. CF8M St. St. | ASTM B16 H.H. Brass Or ASTM B62 Bronze | ASTM B16 H.H. Brass Or ASTM B62 Bronze |
| 2        | Bonnet                      | SA-216 Gr. WCB Carb. St.                            | SA-351 Gr. CF8M St. St.                             | ASTM A126 Cl.B Cast Iron               | ASTM B62 Bronze                        |
| 3        | Disc                        | 316 St. St.   | 316 St. St.   | Brass                                  | Brass                                  |
| 4        | Blow Down Ring              | St. St.   | 316 St. St.   | Brass                                  | Brass                                  |
| 5        | Cap                         | Carbon St.  | 316 St. St.   | Iron                                   | Bronze                                 |
| 6        | Stem                        | St. St.   | 316 St. St.   | St. St.                                | Brass                                  |
| 7        | Spring Adj. Screw           | St. St.   | 316 St. St.   | Brass                                  | Brass                                  |
| 8        | Jam Nut                     | St. St.   | 316 St. St.   | Brass                                  | Brass                                  |
| 9        | Spring Button (Upper)       | Carbon St. Rust Proofed                             | 316 St. St.   | Carbon St. Rust Proofed                | St. St.                                |
| 10       | Spring Button (Lower)       | Carbon St. Rust Proofed                             | 316 St. St.   | Carbon St. Rust Proofed                | St. St.                                |
| 11       | Cap Gasket                  | Flexible Graphite                                   | 316 St. St.   | Flexible Graphite                      | Flexible Graphite                      |
| 12       | Stem Retainer               | St. St.   | 316 St. St.   | —                                      | —                                      |
| 13       | Lockwasher                  | St. St.   | 316 St. St.   | —                                      | —                                      |
| 14       | Groov-Pin                   | —   | —   | St. St.                                | —                                      |
| 15       | Retaining Ring              | —   | —   | —                                      | St. St.                                |
| 16       | Wire Seal                   | Stainless Steel Wire/Lead Seal                      |   |  |  |
| 17       | Nameplate (not shown)       | Stainless Steel                                     |   |  |  |
| 18       | Spring                      | See Selection Table                                 |   |  |  |
| NOTE 1   | Lap Joint Stub End (Inlet)  | SA-403. Gr. WP316 St. St.                           | SA-403 Gr. WP316 St. St.                            | NOT AVAILABLE                          |  |
|          | Lap Joint Stub End (Outlet) | SA-234 Carbon St.                                   | SA-403 Gr. WP316 St. St.                            |  |  |
|          | Lap Joint Flange (Inlet)    | SA-181 or SA-105 Carb. St.                          | SA-182 Gr. F316 St. St.                             |  |  |
|          | Lap Joint Flange (Outlet)   | SA-181 or SA-105 Carb. St.                          | SA-182 Gr. F316 St. St.                             |  |  |

- Notes:**
1. Applicable to the F1850 Series (flanged).
  2. Also suitable for liquid service where ASME Code certification is not required.
  3. The 1856M(C) open lever and packed lever constructions use a stem retainer design similar to internals shown for the 1850 Series.
  4. All open lever types are provided with an untapped hole in bonnet for drainage of condensate.
  5. Series 1850 (3/4") and 1850H (1") supplied with body gasket in the same materials as the cap gasket.

**GENERAL NOTES**  
**ALL SERIES**

1. Available with the following cap constructions:

| Cap Construction | Add As Suffix To Type Number |
|------------------|------------------------------|
| Open Lever       | -OL                          |
| Packed Lever     | -PKD                         |
| Test Gag         | W/TG                         |

2. Available with "O" Ring Seat Pressure Seal option (not illustrated) — add "R" to type number.

Examples: 1850R  
1856MR-PKD

Choice of elastomers includes Buna N, Viton, silicone, ethylene propylene and Kalrez.

3. Test lever required for air, steam and hot water (above 140°F) service.

**SELECTION TABLE**



**SCREWED VALVES**

**SERIES 1850/1850H**

**MNPT INLET x FNPT OUTLET**

| Type Number | Maximum Set Pressure, PSIG |     |      |     |     |             | Inlet Temp. Range °F | Max. Back Press. PSIG | Materials                |                            |
|-------------|----------------------------|-----|------|-----|-----|-------------|----------------------|-----------------------|--------------------------|----------------------------|
|             | Inlet Outlet               | ¾ 1 | 1 1½ | 2 3 | 3 4 | Body/Bonnet |                      |                       | Spring                   |                            |
| 1850        |                            | 300 | 300  | 300 | 300 | 300         | -20 to 400           | 50                    | 316 St. St./ Carbon St.  | Carbon Steel, Rust Proofed |
| 1850H       |                            | —   | 800  | —   | —   | —           |                      |                       |                          | High Temp. Alloy (Note 2)  |
| 1852        |                            | 300 | 300  | 300 | 300 | 300         | 400 to 750           | 50                    | 316 St. St./ 316 St. St. | High Temp. Alloy (Note 2)  |
| 1852H       |                            | —   | 800  | —   | —   | —           |                      |                       |                          | 316 St. St.                |
| 1850/S4     |                            | 300 | 300  | 300 | 300 | 300         | -400 to 400          | 50                    | 316 St. St./ 316 St. St. | High Temp. Alloy (Note 3)  |
| 1850H/S4    |                            | —   | 800  | —   | —   | —           |                      |                       |                          | 316 St. St.                |
| 1852/S4     |                            | 300 | 300  | 300 | 300 | 300         | 401 to 750           | 50                    | 316 St. St./ 316 St. St. | High Temp. Alloy (Note 3)  |
| 1852H/S4    |                            | —   | 800  | —   | —   | —           |                      |                       |                          | High Temp. Alloy (Note 3)  |

**Notes:**

- For ½" x 1" size see 1890 Series in Catalog 488C.
- Above 400°F High Temperature Alloy Steel, Plated or High Temperature Stainless Alloy is required.
- Above 400°F in S4 Types, High Temperature Alloy Steel, Nickel Plated or High Temperature Stainless Alloy is required.

**SERIES 1855/1856M**

**MNPT INLET x FNPT OUTLET**

| Type Number | Maximum Set Pressure, PSIG |     |      |      |      |      |      |      |      |      |      | Inlet Temp. Range °F | Max. Back Press. PSIG | Materials                  |                            |
|-------------|----------------------------|-----|------|------|------|------|------|------|------|------|------|----------------------|-----------------------|----------------------------|----------------------------|
|             | Inlet Outlet               | ¾ 1 | 1 1½ | 2 2½ | 2½ 3 | 3 3½ | 3½ 4 | 4 4½ | 4½ 5 | 5 5½ | 5½ 6 |                      |                       | Body/Bonnet                | Spring                     |
| 1855        |                            | 250 | —    | 250  | —    | 250  | —    | 250  | —    | 250  | 250  | -20 to 400           | 50                    | Brass or Bronze/ Cast Iron | Carbon Steel, Rust Proofed |
| 1856MC      |                            | —   | —    | —    | —    | —    | —    | —    | —    | 250  | —    |                      |                       |                            | 250                        |
| 1856M       |                            | —   | 300  | —    | 200  | —    | 250  | —    | 250  | —    | 250  | -400 to 400          | 50                    | Brass or Bronze/ Bronze    | 316 St. St.                |

**Note:**

For ½" x ¾" and ¾" x ¾" sizes see 1895/1896M Series in Catalog 488C.

# CAPACITY SELECTION



TO USE THE CAPACITY TABLES, LOCATE THE TYPE NUMBER AND VALVE SIZE. REFER TO THE CORRECT COLUMN IN THE APPLICABLE FLUID TABLE.

| Series | Valve Size  |           |           |               |           |           |       |
|--------|-------------|-----------|-----------|---------------|-----------|-----------|-------|
|        | 3/4 x 1     | 1 x 1 1/2 | —         | 1 1/2 x 2     | 2 x 3     | 3 x 4     | —     |
| 1850   | 3/4 x 1     | 1 x 1 1/2 | —         | 1 1/2 x 2     | 2 x 3     | 3 x 4     | —     |
| 1850H  | 1 x 1 1/2   | —         | —         | —             | —         | —         | —     |
| 1855   | 3/4 x 1 1/4 | 1 x 1 1/2 | —         | 1 1/2 x 2 1/2 | 2 x 3     | 2 1/2 x 4 | 3 x 4 |
| 1856M  | 1 x 1 1/4   | —         | 1 1/2 x 2 | 2 x 2 1/2     | 2 1/2 x 3 | 3 x 4     | —     |
| Column | A           | B         | C         | D             | E         | F         | G     |

# CAPACITIES



ASME PRESSURE VESSEL CODE (UV) 90% RATING

| AIR<br>10% OVERPRESSURE<br>Capacities in Standard Cubic Feet<br>Per Minute at 60°F. |      |      |      |      |      |      |       |
|---|------|------|------|------|------|------|-------|
| Set Pressure (PSIG)   | A    | B    | C    | D    | E    | F    | G     |
| 1# Incr.  | 3    | 5    | 9    | 13   | 20   | 35   | 50    |
| 5# Incr.  | 16   | 27   | 44   | 63   | 101  | 175  | 252   |
| 10# Incr.   | 32   | 54   | 88   | 126  | 202  | 350  | 504   |
| 15  | 94   | 161  | 261  | 376  | 602  | 1041 | 1499  |
| 20  | 108  | 185  | 301  | 433  | 694  | 1200 | 1728  |
| 40  | 169  | 289  | 468  | 674  | 1080 | 1868 | 2691  |
| 60  | 232  | 397  | 644  | 927  | 1485 | 2568 | 3700  |
| 80  | 295  | 505  | 819  | 1180 | 1889 | 3268 | 4708  |
| 100   | 358  | 613  | 995  | 1433 | 2294 | 3968 | 5717  |
| 120   | 421  | 722  | 1170 | 1685 | 2699 | 4668 | 6725  |
| 140   | 485  | 830  | 1346 | 1938 | 3104 | 5368 | 7734  |
| 160   | 548  | 938  | 1521 | 2191 | 3508 | 6068 | 8742  |
| 180   | 611  | 1046 | 1697 | 2444 | 3913 | 6768 | 9751  |
| 200   | 674  | 1154 | 1873 | 2696 | 4318 | 7468 | 10759 |
| 220   | 737  | 1263 | 2048 | 2949 | 4723 | 8168 | 11768 |
| 240   | 800  | 1371 | 2224 | 3202 | 5127 | 8868 | 12777 |
| 250   | 832  | 1425 | 2311 | 3328 | 5330 | 9218 | 13281 |
| 260   | 864  | 1479 | 2399 | 3455 | 5532 |      |       |
| 280   | 927  | 1587 | 2575 | 3707 | 5937 |      |       |
| 300   | 990  | 1695 | 2750 | 3960 | 6342 |      |       |
| 400   | 1306 |      |      |      |      |      |       |
| 500   | 1622 |      |      |      |      |      |       |
| 600   | 1938 |      |      |      |      |      |       |
| 700   | 2254 |      |      |      |      |      |       |
| 800   | 2570 |      |      |      |      |      |       |

| STEAM<br>10% OVERPRESSURE<br>Capacities in Pounds<br>Per Hour at Saturation Temperature |      |      |      |       |       |       |       |
|---|------|------|------|-------|-------|-------|-------|
| Set Pressure (PSIG)   | A    | B    | C    | D     | E     | F     | G     |
| 1# Incr.  | 9    | 15   | 25   | 36    | 57    | 98    | 142   |
| 5# Incr.  | 44   | 76   | 123  | 178   | 284   | 492   | 708   |
| 10# Incr.   | 89   | 152  | 247  | 355   | 569   | 983   | 1417  |
| 15  | 264  | 452  | 733  | 1056  | 1690  | 2923  | 4212  |
| 20  | 304  | 521  | 845  | 1217  | 1949  | 3370  | 4856  |
| 40  | 474  | 811  | 1316 | 1895  | 3034  | 5248  | 7561  |
| 60  | 651  | 1115 | 1809 | 2605  | 4171  | 7215  | 10394 |
| 80  | 829  | 1419 | 2302 | 3315  | 5308  | 9182  | 13228 |
| 100   | 1006 | 1723 | 2795 | 4025  | 6446  | 11148 | 16062 |
| 120   | 1184 | 2027 | 3288 | 4735  | 7583  | 13115 | 18895 |
| 140   | 1361 | 2331 | 3782 | 5446  | 8720  | 15082 | 21729 |
| 160   | 1539 | 2635 | 4275 | 6156  | 9857  | 17049 | 24562 |
| 180   | 1716 | 2939 | 4768 | 6866  | 10994 | 19016 | 27396 |
| 200   | 1894 | 3243 | 5261 | 7576  | 12131 | 20983 | 30230 |
| 220   | 2072 | 3547 | 5754 | 8286  | 13269 | 22949 | 33063 |
| 240   | 2249 | 3851 | 6247 | 8996  | 14406 | 24916 | 35897 |
| 250   | 2338 | 4003 | 6494 | 9351  | 14974 | 25900 | 37314 |
| 260   | 2427 | 4155 | 6741 | 9706  | 15543 |       |       |
| 280   | 2604 | 4459 | 7234 | 10417 | 16680 |       |       |
| 300   | 2782 | 4763 | 7727 | 11127 | 17817 |       |       |
| 400   | 3669 |      |      |       |       |       |       |
| 500   | 4557 |      |      |       |       |       |       |
| 600   | 5445 |      |      |       |       |       |       |
| 700   | 6332 |      |      |       |       |       |       |
| 800   | 7220 |      |      |       |       |       |       |

**Notes:**

- Capacities for Air and Steam at 30 PSIG and below are based on 3 PSI overpressure.
- Incremental capacities: determine the capacity at any set pressure by adding or subtracting the correct incremental value to any capacity listed.
- Set pressure limit of the 1855 Series is 250 psig as shown by the Grey colored line. Set pressure limit of the 1850 Series is 300 psig as shown by the Brown colored line. Maximum set pressure Series 1850H is 800 psig. For 1856M Series pressure limits, consult the selection table.

# CAPACITY SELECTION

TO USE THE CAPACITY TABLES, LOCATE THE TYPE NUMBER AND VALVE SIZE.  
REFER TO THE CORRECT COLUMN IN THE APPLICABLE FLUID TABLE.

| Series | Valve Size  |           |           |               |           |           |       |
|--------|-------------|-----------|-----------|---------------|-----------|-----------|-------|
|        | 3/4 x 1     | 1 x 1 1/2 | —         | 1 1/2 x 2     | 2 x 3     | 3 x 4     | —     |
| 1850   | 3/4 x 1     | 1 x 1 1/2 | —         | 1 1/2 x 2     | 2 x 3     | 3 x 4     | —     |
| 1850H  | 1 x 1 1/2   | —         | —         | —             | —         | —         | —     |
| 1855   | 3/4 x 1 1/4 | 1 x 1 1/2 | —         | 1 1/2 x 2 1/2 | 2 x 3     | 2 1/2 x 4 | 3 x 4 |
| 1856M  | 1 x 1 1/4   | —         | 1 1/2 x 2 | 2 x 2 1/2     | 2 1/2 x 3 | 3 x 4     | —     |
| Column | A           | B         | C         | D             | E         | F         | G     |

## CAPACITIES

NON-CODE 90% RATING



| WATER<br>25% OVERPRESSURE<br>Capacities in U.S. Gallons<br>Per Minute at 70°F (See Note 1) |    |    |     |     |     |     |     |
|--|----|----|-----|-----|-----|-----|-----|
| Set Pressure (PSIG)  | A  | B  | C   | D   | E   | F   | G   |
| 15   | 10 | 18 | 26  | 40  | 71  | 111 | 162 |
| 20   | 11 | 20 | 29  | 45  | 81  | 126 | 183 |
| 40   | 17 | 30 | 43  | 67  | 119 | 186 | 270 |
| 60   | 21 | 36 | 53  | 82  | 146 | 227 | 331 |
| 80   | 24 | 42 | 61  | 95  | 168 | 263 | 382 |
| 100  | 27 | 47 | 68  | 106 | 188 | 294 | 427 |
| 120  | 29 | 52 | 74  | 116 | 206 | 322 | 468 |
| 140  | 32 | 56 | 80  | 125 | 222 | 347 | 505 |
| 160  | 34 | 60 | 86  | 134 | 238 | 371 | 540 |
| 180  | 36 | 63 | 91  | 142 | 252 | 394 | 573 |
| 200  | 38 | 67 | 96  | 150 | 266 | 415 | 604 |
| 220  | 40 | 70 | 101 | 157 | 279 | 436 | 633 |
| 240  | 41 | 73 | 105 | 164 | 291 | 455 | 661 |
| 250  | 42 | 74 | 107 | 168 | 297 | 464 | 675 |
| 260  | 43 | 76 | 110 | 171 | 303 |     |     |
| 280  | 45 | 79 | 114 | 177 | 314 |     |     |
| 300  | 46 | 81 | 118 | 184 | 325 |     |     |
| 400  | 53 |    |     |     |     |     |     |
| 500  | 60 |    |     |     |     |     |     |
| 600  | 65 |    |     |     |     |     |     |
| 700  | 71 |    |     |     |     |     |     |
| 800  | 75 |    |     |     |     |     |     |

**Notes:**

- To determine capacity at 10% overpressure multiply the capacity at 25% overpressure by 0.6.
- Set pressure limit of the 1855 Series is 250 psig as shown by the Grey colored line.  
Set pressure limit of the 1850 Series is 300 psig as shown by the Brown colored line.  
Maximum set pressure Series 1850H is 800 psig. For 1856M Series pressure limits, consult the selection table.

## EFFECTIVE ORIFICE AREAS

(SQ. IN.)

| Inlet Size | 1850         |                      | 1850H        |                      | 1855         |                      | 1856M        |                      |
|------------|--------------|----------------------|--------------|----------------------|--------------|----------------------|--------------|----------------------|
|            | Liquids Only | Vapors Gases & Steam |
| 3/4        | 0.098        | 0.163                | —            | —                    | 0.098        | 0.163                | —            | —                    |
| 1          | 0.173        | 0.280                | 0.098        | 0.163                | 0.173        | 0.280                | 0.098        | 0.163                |
| 1 1/2      | 0.390        | 0.653                | —            | —                    | 0.390        | 0.653                | 0.250        | 0.452                |
| 2          | 0.691        | 1.048                | —            | —                    | 0.691        | 1.048                | 0.390        | 0.653                |
| 2 1/2      | —            | —                    | —            | —                    | 1.080        | 1.811                | 0.691        | 1.048                |
| 3          | 1.080        | 1.811                | —            | —                    | 1.570        | 2.617                | 1.080        | 1.811                |

**Note:**

For sizing purposes, the coefficients of discharge  $K_d$  are 0.953 for air, gas and vapor, 0.64 for liquids.

kevlar  
1.  
4

## Du Pont Material Safety Data Sheet

### MATERIAL IDENTIFICATION

NAME : KEVLAR\* ARAMID FIBER - DU PONT

TRADE NAMES / SYNONYMS :  
KEVLAR Aramid Yarn  
KEVLAR Aramid Staple  
KEVLAR Aramid Pulp  
KEVLAR Aramid Floc  
KEVLAR Aramid Fabric

DU PONT REGISTRY NUMBER : DP5-73-6  
TSCA INVENTORY STATUS : Reported/Included  
MANUFACTURER/DISTRIBUTOR: E. I. du Pont de Nemours & Co. (Inc.)  
1007 Market Street  
Wilmington, DE 19898  
Date Prepared: 07/26/89  
Preparer: E. A. Merriman  
1-800-453-8527

TRANSPORTATION EMERGENCY PHONE : CHEMTREC: 1-800-424-9300  
MEDICAL EMERGENCY PHONE : 1-800-441-3637

### COMPONENTS

| Material  | CAS Number | %       |
|---|------------|---------|
| Poly(terephthaloylchloride-p-phenylene diamine):                | 26125-61-1 | >89     |
| Water, absorbed (pulp shipped as wetlap contains up to 35%-50%) | 7732-18-5  | < or =7 |
| Sodium sulfate : in KEVLAR pulp                                 | 7757-82-6  | <0.1    |
| : In other forms  |            | <2      |
| Finish  | None       | <2      |
| Wax overlay, in addition to above, on yarn types-960, 978 only  | 6474-43-4  | <10     |

### PHYSICAL DATA

Melting Point : Does not melt.  
Solubility in Water : Insoluble in water.  
Odor : Odorless.  
Color : Gold.  
Specific Gravity : 1.44  
Form : Solid - continuous multi-filament yarns, staple, cut floc, pulp fabric.  
% Volatiles : < 9%, water and finish. (<50% water, <.5% finish in wetlap)

Kevlar

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**(HEALTH HAZARD INFORMATION - CONTINUED)****Safety Precautions**

Avoid breathing fibers or dust. Follow good industrial hygiene practices for ventilation and clean-up; in particular avoid the use of air jets to blow off equipment; use vacuum cleaners with high efficiency particulate air (HEPA) filters instead.

Do not handle moving threadlines of KEVLAR<sup>®</sup>, as entanglement with a high strength fiber can severely cut or even sever fingers.

**FIRST AID**

**INHALATION:** If large amounts of fibers are inhaled, remove to fresh air. If breathing is difficult, give oxygen, and call a physician

**SKIN CONTACT:** If fibers irritate the skin, wash with soap and water.

**PROTECTION INFORMATION****Generally Applicable Control Measures and Procedures**

If the fibers or parts made from the fibers are cut or otherwise mechanically worked, dusts and fibers may be generated. Use engineering controls where technically feasible such as isolation, enclosures, exhaust ventilation, wetting, and dust collection systems wherever necessary to control airborne respirable fiber exposures below applicable limits.

Loose fitting clothing that is routinely washed is recommended to reduce build up of fibers at chafing points.

Laser cutting of fabric of KEVLAR or of laminates containing KEVLAR or machining that produces smoke should be well exhausted or ventilated to remove fumes from the workplace.

Water jet cutting of fabric or composites of KEVLAR produces fibrils in the cutting waste. If dried, this waste can become a source of airborne respirable fibers. Rinse or wipe waste from work surfaces and parts.

**Personal Protective Equipment****EYE/FACE PROTECTION**

When cutting or mechanically working this product, wear safety glasses or coverall goggles.

**RESPIRATORS**

When cutting or mechanically working this product wear NIOSH/MSHA approved respiratory protection if there is potential for airborne exposures in excess of applicable limits, or if there is potential for irritation of the nasal passages to occur due to the mechanical action of the fibers.

kevlar

3.

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(HEALTH HAZARD INFORMATION CONTINUED)

ANIMAL DATA (CONTINUED):

respirable content) showed mild fibrosis at concentrations of 25 fibers per cubic centimeter and lung tumors (cystic keratinizing squamous cell carcinomas) in some rats in the group exposed to respirable fibers at concentrations of 100 fibers per cubic centimeter. This is a unique type of tumor not found in humans and may be indicative of a nonspecific biological response to the respirable material rather than an indication of KEVLAR® toxicity. No lung tumors and no fibrosis were seen in animals exposed to 2.5 respirable fibers per cubic centimeter for two years. At no concentrations were fibers found to have migrated beyond the lungs and associated lymph system. Abdominal cavity tumors have been observed in two studies where rats were administered KEVLAR by intra-cavity injection. For additional details, see References.

HUMAN DATA.

Skin sensitization has not been observed in human skin tests. The mechanical action of the fibers may cause slight skin irritation at clothing binding points and mild irritation of the eyes and nasal passages. Overexposure to the respirable fibers by inhalation may cause mild and temporary upper respiratory irritation with discomfort or cough. Based on animal testing, prolonged and repeated exposure to excessive concentrations may cause permanent lung injury.

Workplace exposure measurements: Measured levels of airborne respirable fibrils from handling and processing KEVLAR pulp and filament yarn are typically 0.3 fibrils/cc, or less, 8-Hour Time Weighted Average (TWA). The normally low airborne dust levels result from the inherent tendency of KEVLAR fibrils to clump together - they have high surface static charges and their branched shapes readily interlock. Staple spinning operations, with their high potential for fiber abrasion can produce levels of 1-3 fibrils/cc unless air handling is well designed and maintained. In all processing of KEVLAR, the use of compressed air to clean equipment can temporarily increase the airborne fibril concentrations markedly. Equipment should be vacuumed or wiped instead.

Carcinogenicity

None of the components in this material is listed by IARC, NTP, OSHA, or ACGIH as a carcinogen. See Animal Data discussed above.

Exposure Limits for KEVLAR ARAMID FIBER - DU PONT

- AEL \* (Du Pont) : 2 respirable fibers/cc (8-Hr. TWA)
- TLV \*\* (ACGIH) : None established.
- PEL (OSHA) : None established.

\* AEL is Du Pont's Acceptable Exposure Limit.

\*\* TLV is a registered trademark of the American Congress of Governmental Industrial Hygienists

Other Applicable Exposure Limits:

Exposure Limits for KEVLAR DUST

- AEL \* (Du Pont) : 5 mg/m3, Total Dust
- TLV \*\* (ACGIH) : None Established.
- PEL (OSHA) : None Established

Particulates Not Otherwise Regulated

- PEL (OSHA) : 15 mg/m3, Total Dust  
5 mg/m3, Respirable Dust

Kevlar  
5  
-49

## DISPOSAL INFORMATION

### Spill, Leak, or Release

Use appropriate PERSONAL PROTECTIVE EQUIPMENT during clean up. Wash, shovel or sweep up and place in solid waste containers. Clean up dusts and fibers with high efficiency particulate air (HEPA) filtered vacuum equipment.

### Waste Disposal

KEVLAR® is not a hazardous waste as defined by regulations implementing the Resource Conservation and Recovery Act (RCRA). In general, KEVLAR waste materials may be discarded in accordance with the State and Local regulations governing the disposal of other common or non-RCRA regulated waste materials.

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## SHIPPING INFORMATION

### DOT

Proper Shipping Name : None, non-regulated

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## STORAGE CONDITIONS

KEVLAR dry pulp should be stored with 4 - 8% absorbed moisture to control static charge.

### Storage:

- Boxes of yarn
- Bales of staple
- Bags of pulp
- Rolls of wetlap
- Rolls of fabric

---

## ADDITIONAL INFORMATION AND REFERENCES

This MSDS is provided to comply with provisions of the Hazard Communication Standard (29 CFR 1910.1200).

Superfund Amendments and Reauthorization Act of 1986 (SARA) Title III: KEVLAR contains no toxic chemicals as regulated under section 313 Emergency Planning and Community Right-to-Know Act (EPCRA) of SARA Title III and 40 CFR part 372. KEVLAR is not regulated as hazardous waste under CERCLA and is not subject to the Superfund tax.

California Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65): KEVLAR contains none of the substances known to the State of California to cause cancer or reproductive toxicity.

Pennsylvania and New Jersey Right-to-Know Laws: KEVLAR is not subject to provisions of the Pennsylvania and New Jersey Right-to-Know laws.

### References:

- Lee, K.P., et al., Toxicology and Applied Pharmacology, 71 (1983), 243-253.
- Lee, K.P., et al., Fundamental and Applied Toxicology, 11 (1988), 1-20.
- Vu, V.T., Health Hazard Assessment of Non-Asbestos Fibers (Final Draft), Office of Toxic Substances, U.S. Environmental Protection Agency, (May, 1988), 19-21, 152-164.

The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that every entry should be supported by a valid receipt or invoice. This ensures transparency and allows for easy verification of the data.

In the second section, the author outlines the various methods used to collect and analyze the data. This includes both primary and secondary data collection techniques. The primary data was gathered through direct observation and interviews with key personnel. Secondary data was obtained from existing reports and databases.

The third section provides a detailed analysis of the findings. It identifies several key trends and patterns in the data. For example, there is a significant increase in sales volume over the period studied, which is attributed to a combination of factors including market expansion and improved operational efficiency.

Finally, the document concludes with a series of recommendations for future action. These are based on the insights gained from the analysis and are designed to help the organization continue to grow and succeed in a competitive market.

Mylar  
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# MATERIAL SAFETY DATA SHEET

SCHARR INDUSTRIES  
40 EAST NEWBERRY ROAD  
BLOOMFIELD, CT 06002

Date revised: 2/9/94  
SCHARR 24 HR. # (203)243-0343

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## SECTION I - PRODUCT IDENTIFICATION

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TRADE NAME: 500 gauge Polyester film metallized (Mylar)  
CHEMICAL FAMILY: Polyethylene Terephthalate  
FORMULA: N/A  
PRIMARY PRODUCT USE: Film Industry related products

---

## SECTION II - HAZARDOUS COMPONENTS

---

| <u>INGREDIENT</u> | <u>CAS #</u> | <u>% (BY WT.)</u> | <u>PEL</u> | <u>TLV</u> |
|-------------------|--------------|-------------------|------------|------------|
|-------------------|--------------|-------------------|------------|------------|

THIS PRODUCT IS NOT REGULATED UNDER THE OSHA HAZARD COMMUNICATION STANDARD,  
29CFR1910.1200 OR SARA TITLE III

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## SECTION III - PHYSICAL PROPERTIES

---

|                      |                 |
|----------------------|-----------------|
| MELTING POINT °F     | : N/A           |
| SOLUBILITY IN WATER  | : INSOLUBLE     |
| ODOR                 | : NONE          |
| PERCENT VOLATILE WT. | : 0.8           |
| APPEARANCE           | : METALLIC FILM |
| STATE                | : SOLID         |

---

**SECTION IV - FIRE & EXPLOSION INFORMATION**

---

FLASH PT. °F : +700°F

**HAZARDOUS DECOMPOSITION PRODUCTS:** Thermal decomposition may form toxic materials: carbon monoxide & carbon dioxide, carbon compounds.

**SPECIAL PRECAUTIONS:** Toxic gases may be released during fire. Use positive-pressure, self-contained breathing apparatus and full protective clothing. Handling of this material may cause generation of electrostatic charges and sparking. Use electrical grounding equipment to minimize charge buildup. Avoid dusting. Dust levels can buildup to explosive levels.

**EXTINGUISHING MEDIA:** Foam or carbon dioxide or dry chemical or Water spray.

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**SECTION V - HEALTH HAZARD DATA**

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**PERMISSIBLE EXPOSURE LEVEL:** NOT DETERMINED

**THRESHOLD LIMIT VALUE:** NOT DETERMINED

**EFFECT OF ACUTE OVEREXPOSURE:**

**EYES** - No specific information. May cause irritation by mechanical contact.  
**SKIN** - No specific information.  
**BREATHING** - No specific information.  
**Swallowing** - No specific information.

**FIRST AID:**

If exposed to fumes from over heating or combustion, move to fresh air. Consult a physician if symptoms persist.

Wash skin with soap and plenty of water.

Flush eyes with water. Consult a physician if symptoms persist.

If molten polymer contacts skin, cool rapidly with cold water. Do not attempt to peel polymer from skin. Obtain medical attention for thermal burn.

**CHRONIC EFFECTS:** None are known.

**MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE:** None are known.

Mylov  
3

3  
52

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**SECTION VI - REACTIVITY DATA**

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**HAZARDOUS POLYMERIZATION:** Cannot occur

**STABILITY:** Stable

**INCOMPATIBILITY:** Avoid contact with: strong oxidizing agents.

---

**SECTION VII - SPILL OR LEAK PROCEDURES**

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**STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED:**

**SPILL OR LEAK PROCEDURES:** Pick up film to avoid a slipping hazard.

**WASTE DISPOSAL:** Dispose of in accordance with all Local, State and Federal Regulations.

---

**SECTION VIII - PROTECTIVE EQUIPMENT TO BE USED**

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**RESPIRATORY PROTECTION:** Not required.

**VENTILATION:** Normal ventilation except at temperatures above 235°C where local ventilation may be required.

**EYE PROTECTION:** Safety goggles or glasses in compliance with OSHA regulations and good industrial safety practices.

**OTHER PROTECTIVE EQUIPMENT:** None required

**SPECIAL PRECAUTIONS:** Use good hygiene practices, wash hands after handling, use good housekeeping practices, keep work area clean.

KTeV 1.8M VACUUM WINDOW

## PART B

VACUUM AND HYDROSTATIC  
TESTS

TESTS DOCUMENTATION  
DATA

-50

March 21, 1994

TO: R. Dixon - Research Division Head

FROM: J. Misek and W. Smart - KTeV ES&H/QA Review Committee

SUBJECT: KTeV 1.8 m Vacuum Window Test Procedure Review Report -

*J. Misek*  
*W. Smart*

Recommendation to Proceed

Pursuant to the Committee charter, a summary report of the compliance status for the KTeV Window Test program - WBS 3.1 is provided. Mechanical aspects were the primary focus of this review, though per the WBS List, electrical and conventional safety aspects were also to be included. The Committee has no electrical or conventional safety concerns for this testing program.

Committee members J. Misek, R. Bossert, E. Haggard, P. Hurh, and W. Smart have reviewed documentation received from KTeV Engineering Staff outlining the testing program and conclude that sound engineering practices have been employed. In addition, the Committee made an inspection walkthru of the test area and viewed the equipment setup. This walkthru was made on 3/2/94 and no deficiencies were noted.

The window testing program does not require adherence to any specific standards set forth in Fermilab's ES&H Manual. The KTeV E-832 1.8 m Vacuum Window Testing Procedure for Vacuum and Hydrostatic Tests dated 3/8/94 is made part of this report. See attachment. Please note that the KTeV Engineering Staff and this Committee have agreed that they will observe the Fermilab Pressure Testing Permit formalism (Fermilab ES&H Manual 5034) with one permit to cover all vacuum testing and a second permit to cover the hydrostatic tests.

In making its recommendation to proceed with window testing in accordance with the attached documentation, the Committee would like to include as part of the documentation file W. Smart's calculations and discussion on the vessel movement from window failure.

Please note that the draft version dated March 4, 1994 of the *Window Assembly Procedure* is the current version. A change in the assembly procedure document does not require formal Committee action.

We recommend that you approve this testing program for the KTeV 1.8 m Vacuum Window.

cc:  
-without attachments-  
W. Smart  
P. Hurh  
R. Bossert  
E. Haggard  
A. Szymulanski  
D. Pushka

*I hereby approve the window testing program for the 1.8 m vacuum window subject to the conditions outlined above.*

*Roger L. Dixon*  
*3-22-94*

File  
Date



# Fermilab

Date MARCH 22, 94

## EXHIBIT B Pressure Testing Permit\*

Type of Test: VACUUM  
 Hydrostatic  Pneumatic  
Test Pressure: 14.7 <sup>NEGATIVE</sup> psig Maximum Allowable Working Pressure: 45 psig

Items to be Tested 1.8 m KTEV VACUUM WINDOW  
REF. DWG. 9220.832. MD-285394

Location of Test M.A.B. Date and Time MARCH 28, 94 9AM

Hazards Involved RUPTURE OF THE WINDOW COMPONENTS,  
WHAT MAY GENERATE ABNORMAL SOUND LEVEL.  
OTHER HAZARDS RELATE TO TYPICAL INDUSTRIAL INSTALLATION WORK

Safety Precautions Taken SEE SUBSECTION 1 OF THIS ELABORATION

Special Conditions or Requirements TESTING PROCEDURE  
HAS TO BE CONSISTENT WITH:  
" KTEV 1.8M VACUUM WINDOW OVERVIEW OF TEST PROCEDURE

Test Coordinator ANDREW SZYMULANSKI Dept/Date \_\_\_\_\_

Division/Section Safety Officer 9, B9 Wilby for T. Sardino Dept/Date RD/ES&H 3-22-94

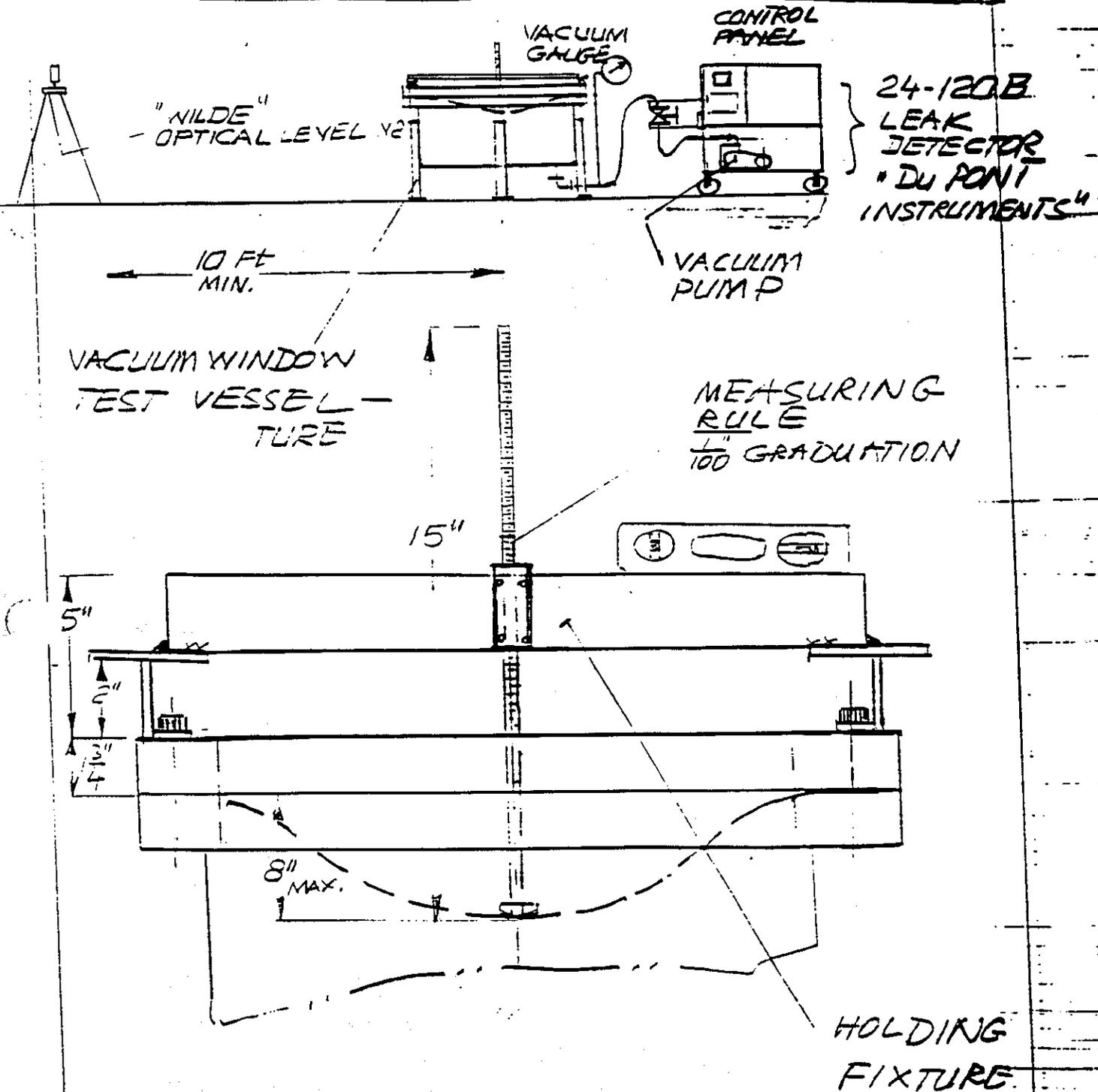
Division/Section Head [Signature] Dept/Date RDO 3/23/94

Results \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Witness \_\_\_\_\_ Dept/Date \_\_\_\_\_  
(Safety Officer or Designee)

\* Must be signed by division/section safety officer and division/section head prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.

2. TESTING SYSTEM SCHEMATIC - VACUUM



4B  
R. Currier  
A. Szymulanski  
March 8, 1994

## KTeV 1.8m Vacuum Window Overview of Test Procedure

This test is required to provide a suitable, safe, non metallic vacuum window for the KTeV experiment, which is running during the next fixed target run. To determine if the design of this window meets all of the parameters of the experiment and the KTeV ES&H Review Committee, the following set of tests were devised. The first test, initial pump down, proves that the window design works. The puncture test will give us an idea how the window will fail, if a hole were to develop (material failure), or was accidentally penetrated. The initial pump down and puncture test will require a single pressure test permit. The hydrostatic test is intended to give us an idea of the safety factor of the window and will require a separate pressure test permit. The long duration creep test will give us information on how the window survives or fails over a long period of time. If there are any deviations from expected results during any test, the tests will be stopped until the deviation can be understood then explained in writing to the KTeV ES&H Review Committee, exactly what happened, why, and how it will affect the rest of the test program. Interesting phases of the test should be put on video tape. Present at the beginning of each phase of the tests should be a representative of the ES&H Dept, the KTeV experiment, the KTeV ES&H Review Committee, Don Carpenter and Andrew Szymulanski.

### Safety considerations:

- A) During the vacuum test, no one will be allowed within 10 feet of the test vessel. This is to be assured by roping off the test area, appropriate signs, (keep-out test in progress), and supervisory vigilance.
- B) Safety glasses and safety shoes are requirements of anyone working at MAB. Test observers will be required to wear safety glasses at all times.
- C) Hearing protection will be required of all personnel in the building during the initial pump down, subsequent pump downs and during the puncture test only.

- 1) Make a kevlar and aluminized mylar, sandwiched window, and assemble with flanges etc. as specified on Dwg.# MD-285394 and attached information. Inform Andrew when starting, so the KTeV ES&H Review Committee and the experiment can be notified.
- 2) Set up for vacuum test as shown on Dwg.#MD-285391 and schematic attached. Arrange for surveyors.
  - 2a) Prepare for pump down by clearing the test area and setting up as specified in A) above. Check for eye and hearing protection and display pressure test permit.
  - 2b) Pump down test chamber to a minimum of 29" Mercury(Hg) and remotely measure and record the deflection of the window every 2 hours. The remote measuring is to be accomplished by using optical surveying instruments looking at the scale mounted in the center of the thin window as shown on page 7B. Shut down overnight and bleed up to atmosphere. Pump down again in the AM recording the deflection every 2 hours. Shut down overnight and bleed up to atmosphere. Pump down again in the AM to 29" Hg then shut down and bleed up to atmosphere.

- 3) Using the same window, prepare for puncture test. Follow the design data of sketch 1'.
  - 3a) Prepare for pump down and puncture test by clearing the test area and setting up as specified in A) above. Check for eye and hearing protection and display pressure test permit.
  - 3b) Set up puncture device as shown on attached sketch, start pumping down test chamber. At 29" of Hg.
  - 3c) After double checking all of the appropriate safety precautions, remotely release spear to puncture window.
  
- 4) Assuming the first window worked, make a second window and proceed to Hydraulic test. Notify surveyors.
  
- 5) Set up for hydrostatic test inside the MAB shop per schematic attached. Assemble test chamber and place 2 legs on a 4 x 4 to elevate bleed valve (as shown on attached sketch). Make sure to display pressure test permit.
  - 5a) Fill test chamber with water (make sure bleed valve is open.) After filled, lift chamber with crane using appropriate slings and rigging techniques. Remove 4 x 4s from under legs. (as shown on attached sketch)
  - 5b) Prepare for hydrostatic test by clearing the test area and setting up as specified in A) above. Check for eye protection.
  - 5c) Pressurize test chamber, as shown in subsection 3, using a ~~hydraulic test pump~~ <sup>BLDG. SUPPLY WATER</sup>, to 15psig then carefully measure the window deflection. Continue to add pressure and remotely measure deflection at 5psig increments, to destruction of window or <sup>40</sup>45psig whichever comes first. (failure expected at 31psig to 38psig)
  - 5d) Clean up mess, then disassemble window flanges and check window, o-ring, and aluminum ring for irregularities.
  
- 6) Using information learned from the fabrication of the first windows, make another window for the long duration, 6 month, creep test.
  - 6a) Find an area in the shop, out of the normal traffic pattern, away from people and well protected from casual contact to set up the test chamber and new window.
  - 6b) Prepare for pump down and long duration creep test by clearing the test area and setting up as specified in A) above.
  - 6c) For the duration of the test, maintain the area to the same degree of security and safety as originally set up.
  - 6d) Test chamber and window are to be under vacuum, with vacuum pump running, 24 hours a day 7 days a week.
  - 6e) Bleed up to atmosphere once per month, over the weekend only.
  - 6f) Record the pressure level in a log at the start and the finish of each working day for the duration of the test. It's not necessary to use a strip chart recorder.

~~GB~~  
R. Currier  
A. Szymulanski  
March 8, 1994

- 6g) It is possible that the window will creep, or move, or maybe even stretch, over a period of time. The result would be an increase in deflection. If the measured deflection is ever greater than the original by 1/4" notify Andrew.
- 6h) Remotely measure and record the deflection of the window each day for the first week.
- 6j) If a measurable change is not indicated during the first week then measure and record the deflection of the window at the end of the first and last day of the second week.
- 6k) If a measurable change is not indicated at the end of the second week then measure and record the deflection of the window at the end of first day of each week for the duration of the test.
- 6m) The duration of the test is expected to be 6 months.
- 6n) If any peculiarities or problems are encountered, call Andrew @ x4870.

# Ktev 1.8 m Kevlar Window #1 Vacuum/Deflection Test

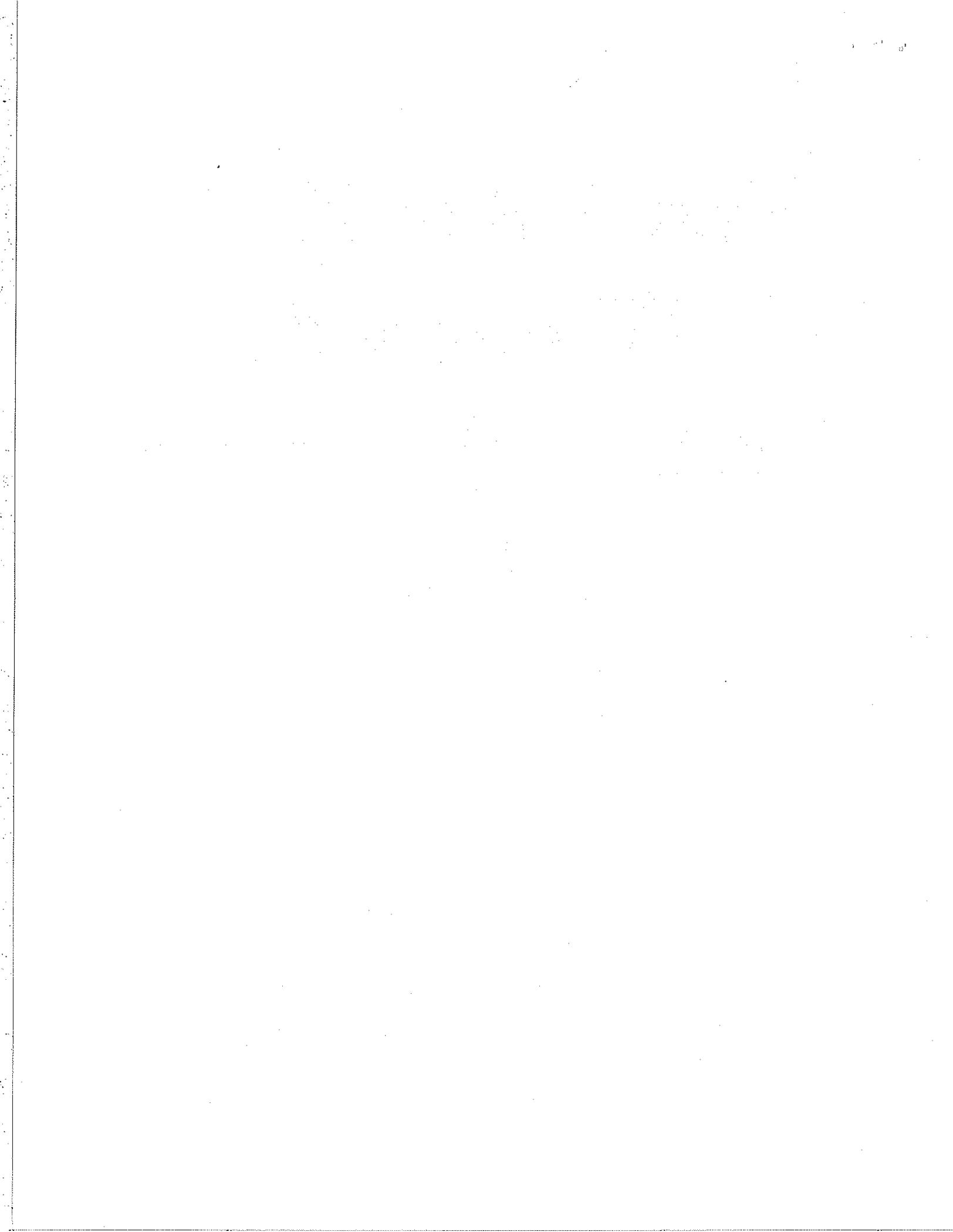
Vacuum Control : Jim Humbert

Surveyor : Glenda Adkins

Observers : Don Carpenter  
: Andrew Szymulanski  
: Joe Misek  
: Dave Erickson

Recorder : Pat Richards

Safety : Martha HEFLIN  
: Jennifer HESS



# Ktev 1.8 m Kevlar Window #1 Vacuum/Deflection Test

-63-

Date : 3/28/94

| Time     | T-2 Reading<br>(Inches) | N3 Reading<br>(Inches) | Bench Reading<br>(Inches) | Pressure<br>(Torr) | Pressure<br>In. Hg.     |
|----------|-------------------------|------------------------|---------------------------|--------------------|-------------------------|
| 9:00 AM  | 4.5                     | 14.621                 | 4.253                     |                    | Atmosphere              |
| 9:26 AM  |                         |                        |                           | 580.000            | -8                      |
| 9:27 AM  |                         |                        |                           | 415.000            | -15                     |
| 9:28 AM  |                         |                        |                           | 320.000            | -20                     |
| 9:29 AM  |                         |                        |                           | 240.000            |                         |
| 9:30 AM  |                         |                        |                           | 135.000            | -28                     |
| 9:31 AM  |                         |                        |                           | 60.000             | -30                     |
| 9:32 AM  |                         |                        |                           | 27.000             | -30                     |
| 9:33 AM  |                         |                        |                           | 9.550              | -30                     |
| 9:34 AM  |                         |                        |                           | 4.120              | -30                     |
| 9:35 AM  |                         |                        |                           | 1.800              | -30                     |
| 9:36 AM  |                         |                        |                           | 0.978              | -30                     |
| 9:37 AM  |                         |                        |                           | 0.670              | -30                     |
| 9:38 AM  |                         |                        |                           | 0.597              | -30                     |
| 9:39 AM  |                         |                        |                           | 0.520              | -30                     |
| 9:40 AM  | 10.695(?)               |                        |                           | 0.460              | -30                     |
| 9:41 AM  |                         |                        |                           | 0.430              | -30                     |
| 9:42 AM  |                         |                        |                           | 0.408              | -30                     |
| 9:43 AM  |                         |                        |                           | 0.390              | -30                     |
| 9:44 AM  |                         |                        |                           | 0.380              | -30                     |
| 9:45 AM  |                         |                        |                           | 0.366              | -30                     |
| 10:00 AM | 10.662                  |                        |                           |                    |                         |
| 10:15 AM |                         |                        |                           | 0.247              | -30                     |
| 10:45 AM |                         |                        |                           | 0.204              | -30                     |
| 11:00 AM | 10.742                  |                        |                           |                    |                         |
| 11:15 AM |                         |                        |                           | 0.182              | -30                     |
| 11:45 AM |                         |                        |                           | 0.168              | -30                     |
| 12:00 PM | 10.756                  |                        |                           |                    |                         |
| 1:00 PM  | 10.795                  |                        |                           | 0.140              | -30                     |
| 2:00 PM  | 10.809                  |                        |                           | 0.128              | -30                     |
| 3:00 PM  |                         |                        |                           | 0.115              | -30                     |
| 3:30 PM  | 10.817                  |                        |                           |                    |                         |
| 4:00 PM  | 10.827                  |                        |                           | 0.107              | -30                     |
| 4:30 PM  |                         |                        |                           | 0.104              | -30                     |
| 4:31 PM  |                         |                        |                           | 0.240              | Vacuum Pump<br>Isolated |

\* Rate of rise 4:30 PM, 3-28-94 to 0800, 3-29-94 = 0.67 T/hr.  
 (Δ Time = 15.5 hr.)  
 (Δ Pressure = 10.396 T)

Ktev 1.8 m Kevlar Window #1 Vacuum/Deflection Test -64-

Date : 3/29/94

| Time     | T-2 Reading<br>(Inches) | N3 Reading<br>(Inches) | Bench Reading<br>(Inches) | Pressure<br>(Torr) | Pressure<br>In. Hg.     |
|----------|-------------------------|------------------------|---------------------------|--------------------|-------------------------|
| 8:00 AM  |                         | 17.704                 | 3.764                     | 11.500             |                         |
| 9:00 AM  |                         | 17.704                 |                           |                    |                         |
| 9:17 AM  |                         |                        |                           | 755.000            |                         |
| 9:18 AM  |                         |                        |                           | 625.000            | 8                       |
| 9:19 AM  |                         |                        |                           | 530.000            | 12                      |
| 9:20 AM  |                         |                        |                           | 435.000            | 16                      |
| 9:21 AM  |                         |                        |                           | 325.000            | 20                      |
| 9:22 AM  |                         |                        |                           | 225.000            | 24                      |
| 9:23 AM  |                         |                        |                           | 130.000            | 28                      |
| 9:24 AM  |                         |                        |                           | 49.000             | 30                      |
| 9:25 AM  |                         |                        |                           | 17.600             | 30                      |
| 9:26 AM  |                         |                        |                           | 6.400              | 30                      |
| 9:27 AM  |                         |                        |                           | 2.330              | 30                      |
| 9:28 AM  |                         |                        |                           | 1.030              | 30                      |
| 9:29 AM  |                         |                        |                           | 0.573              | 30                      |
| 9:30 AM  |                         | 17.661                 |                           | 0.405              | 30                      |
| 10:15 AM |                         |                        |                           | 0.132              | 30                      |
| 10:30 AM |                         | 17.707                 |                           |                    |                         |
| 11:00 AM |                         |                        |                           | 0.106              | 30                      |
| 11:30 AM |                         | 17.722                 |                           |                    |                         |
| 11:45 AM |                         |                        |                           | 0.093              | 30                      |
| 1:00 PM  |                         | 17.734                 |                           | 0.083              | 30                      |
| 2:00 PM  |                         |                        |                           | 0.078              | 30                      |
| 3:00 PM  |                         |                        |                           | 0.073              | 30                      |
| 3:30 PM  |                         | 17.744                 |                           |                    |                         |
| 4:00 PM  |                         |                        |                           | 0.069              | 30                      |
| 4:30 PM  |                         | 17.749                 |                           | 0.067              | 30                      |
| 4:30 PM  |                         |                        |                           | 0.162              | Vacuum Pump<br>Isolated |

\* Rate of rise 4:30 PM, 3-29-94 to 0800, 3-30-94 = 0.66 T/hr.  
 (Δ Time = 15.5 hr.)  
 (Δ Pressure = 10.233 T)

**Ktev 1.8 m Kevlar Window #1 Vacuum/Deflection Test -65-**

Date : 3/30/94

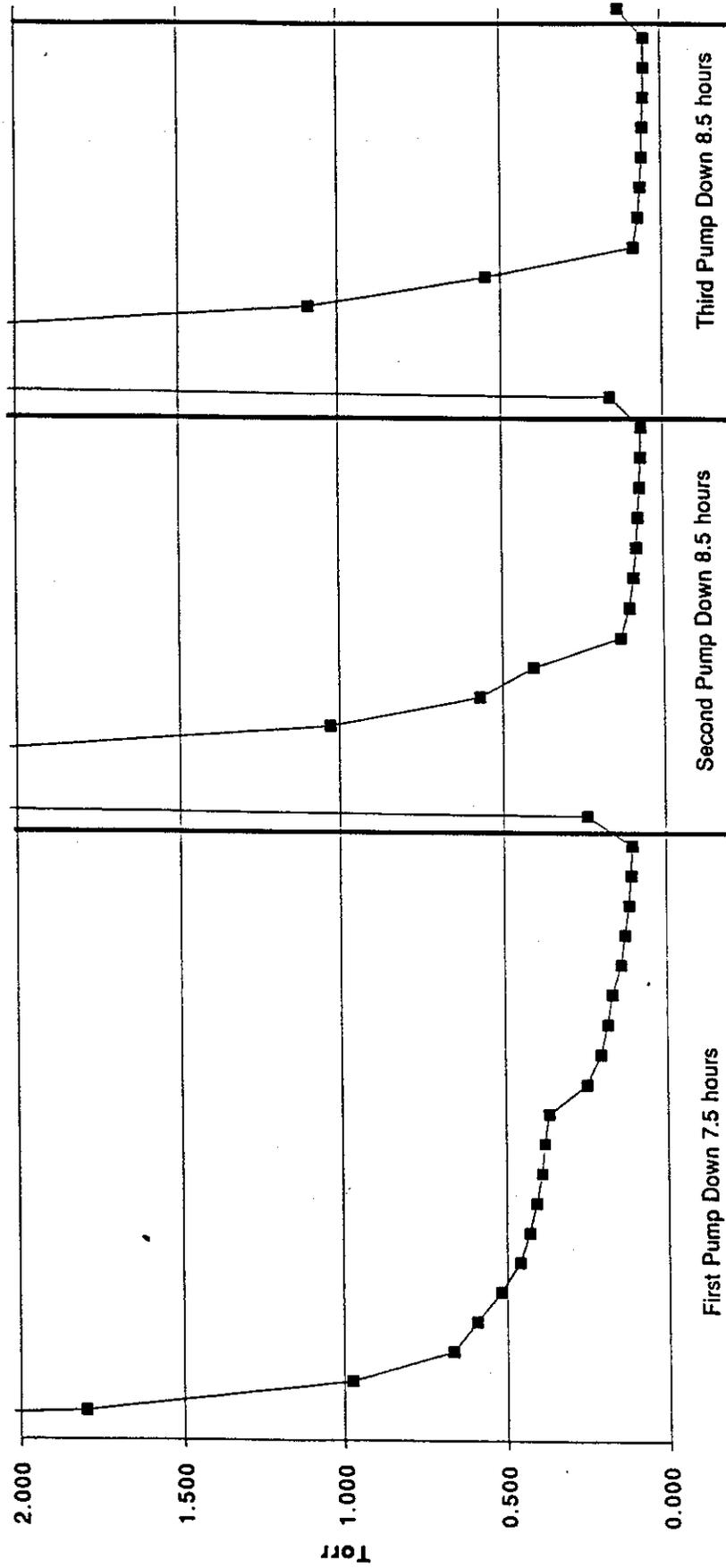
| Time     | T-2 Reading (Inches) | N3 Reading (Inches) | Bench Reading (Inches) | Pressure (Torr) | Pressure In. Hg.     |
|----------|----------------------|---------------------|------------------------|-----------------|----------------------|
| 8:00 AM  |                      | 17.778              | 3.773                  | 10.300          | Vacuum Off           |
| 8:40 AM  |                      | 15.846              |                        |                 | Atmosphere           |
| 8:45 AM  |                      |                     |                        | 760.000         |                      |
| 8:46 AM  |                      |                     |                        | 620.000         |                      |
| 8:47 AM  |                      |                     |                        | 470.000         |                      |
| 8:48 AM  |                      |                     |                        | 385.000         |                      |
| 8:49 AM  |                      |                     |                        | 300.000         |                      |
| 8:50 AM  |                      |                     |                        | 220.000         |                      |
| 8:51 AM  |                      |                     |                        | 120.000         |                      |
| 8:52 AM  |                      |                     |                        | 53.000          |                      |
| 8:53 AM  |                      |                     |                        | 20.400          |                      |
| 8:54 AM  |                      |                     |                        | 7.500           |                      |
| 8:55 AM  |                      |                     |                        | 2.600           |                      |
| 8:56 AM  |                      |                     |                        | 1.090           |                      |
| 8:57 AM  |                      |                     |                        | 0.550           |                      |
| 9:00 AM  |                      | 17.724              |                        |                 |                      |
| 9:02 AM  |                      | 17.736              |                        |                 |                      |
| 10:00 AM |                      |                     |                        | 0.088           |                      |
| 11:00 AM |                      | 17.778              |                        | 0.073           |                      |
| 12:00 PM |                      |                     |                        | 0.066           |                      |
| 1:00 PM  |                      |                     |                        | 0.061           |                      |
| 1:05 PM  |                      | 17.783              |                        |                 |                      |
| 2:00 PM  |                      |                     |                        | 0.058           |                      |
| 3:00 PM  |                      | 17.787              |                        | 0.055           |                      |
| 4:00 PM  |                      |                     |                        | 0.053           |                      |
| 4:30 PM  |                      |                     |                        | 0.053           |                      |
| 4:30 PM  |                      | 17.791              | 3.774                  | 0.131           | Vacuum Pump Isolated |

| Time    | T-2 Reading (Inches) | N3 Reading (Inches) | Bench Reading (Inches) | Pressure (Torr) | Pressure In. Hg. |
|---------|----------------------|---------------------|------------------------|-----------------|------------------|
| 8:15 AM |                      | 17.798              | 3.772                  | 9.600           |                  |
| 9:13 AM |                      | 16.196              | 3.772                  |                 |                  |
|         |                      |                     |                        |                 |                  |

\* Rate of rise 4:30 PM, 3-30-94 to 0800, 3-31-94 = 0.612 T/hr.  
 (Δ Time = 15.5 hr.)  
 (Δ Pressure = 9.547 T)

# Ktey 1.8 m Kevlar Window #1 Vacuum/Deflection Test

## Pressure Study



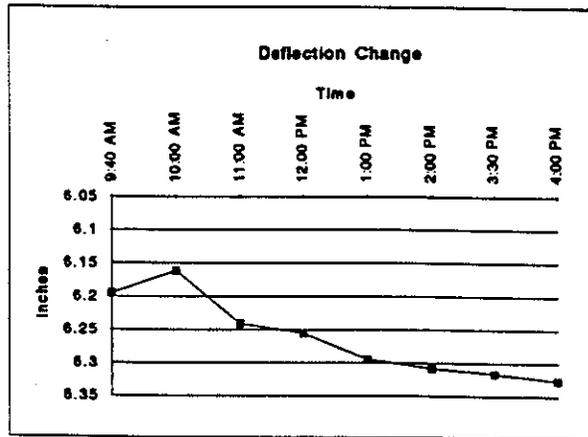
**Ktey 1.8 m Kevlar Window #1 Vacuum/Deflection Test**

67.

**March 28, 1994 First Pump Down  
Scale Readings in inches of Deflection**

| Time     | Readings |
|----------|----------|
| 9:00 AM  | 4.5      |
| 9:40 AM  | 10.895   |
| 10:00 AM | 10.662   |
| 11:00 AM | 10.742   |
| 12:00 PM | 10.758   |
| 1:00 PM  | 10.795   |
| 2:00 PM  | 10.809   |
| 3:30 PM  | 10.817   |
| 4:00 PM  | 10.827   |

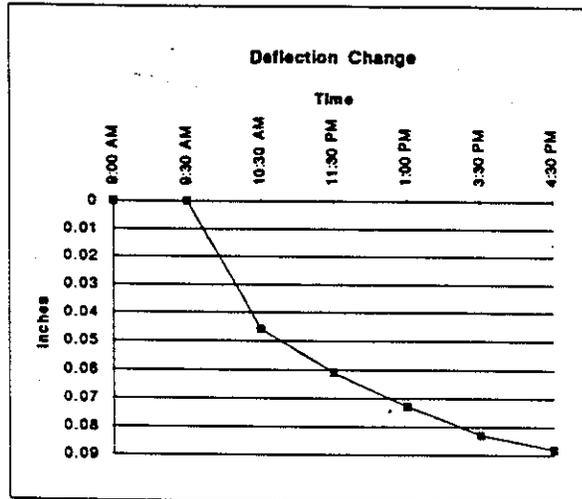
| Time     | Change<br>in inches |
|----------|---------------------|
| 9:00 AM  |                     |
| 9:40 AM  | 6.195               |
| 10:00 AM | 6.182               |
| 11:00 AM | 6.242               |
| 12:00 PM | 6.258               |
| 1:00 PM  | 6.295               |
| 2:00 PM  | 6.309               |
| 3:30 PM  | 6.317               |
| 4:00 PM  | 6.327               |



**March 29, 1994 Second Pump Down  
Scale Readings in Inches of Deflection**

| Time     | Readings |
|----------|----------|
| 8:00 AM  | 17.704   |
| 9:00 AM  | 17.704   |
| 9:30 AM  | 17.661   |
| 10:30 AM | 17.707   |
| 11:30 PM | 17.722   |
| 1:00 PM  | 17.734   |
| 3:30 PM  | 17.744   |
| 4:30 PM  | 17.749   |

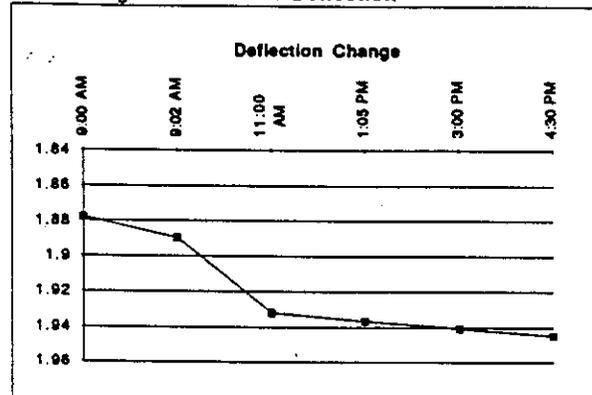
| Time     | Change<br>in inches |
|----------|---------------------|
| 8:00 AM  |                     |
| 9:00 AM  | 0                   |
| 9:30 AM  | 0                   |
| 10:30 AM | 0.046               |
| 11:30 PM | 0.061               |
| 1:00 PM  | 0.073               |
| 3:30 PM  | 0.083               |
| 4:30 PM  | 0.088               |



**March 30, 1994 Third Pump Down  
Scale Readings in Inches of Deflection**

| Time     | Reading |
|----------|---------|
| 8:00 AM  | 17.778  |
| 8:40 AM  | 15.846  |
| 9:00 AM  | 17.724  |
| 9:02 AM  | 17.736  |
| 11:00 AM | 17.778  |
| 1:05 PM  | 17.783  |
| 3:00 PM  | 17.787  |
| 4:30 PM  | 17.791  |

| Time     | Inches |
|----------|--------|
| 8:00 AM  | 1.878  |
| 9:02 AM  | 1.89   |
| 11:00 AM | 1.932  |
| 1:05 PM  | 1.937  |
| 3:00 PM  | 1.941  |
| 4:30 PM  | 1.945  |





- TESTS :
- ④ AUGUST 23, 94
  - ③ AUGUST 1, 94
  - ② JULY 18, 94
  - ① JUN 27, 94

Date JUN 27, 94

**EXHIBIT B**  
**Pressure Testing Permit\***

Type of Test:  Hydrostatic  Pneumatic

Test Pressure: 40 psig Maximum Allowable Working Pressure: 45 psig

Items to be Tested 1.8M VACUUM WINDOW

REF. DWG. 9220.832.MD-285394

STEEL VESSEL 45 psi  
WINDOW ASSEMBLY 40

Location of Test M.A.R. Date and Time \_\_\_\_\_

Hazards Involved FAILURE OF THE TESTED COMPONENTS;  
FLYING DEBRIS

Safety Precautions Taken SEE SUBSECTION 1 OF:

KTEV E-832 1.8M VACUUM WINDOW TESTING PROCEDURE

Special Conditions or Requirements: TESTING PROCEDURE HAS TO BE CONSISTENT  
WITH: "KTEV 1.8M VACUUM WINDOW OVERVIEW  
OF TEST PROCEDURE"

Test Coordinator ANDREW SZYMULANSKI Dept/Date \_\_\_\_\_

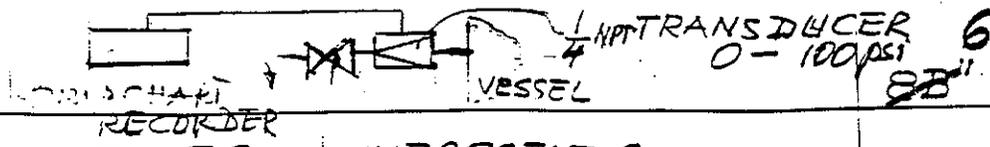
Division/Section Safety Officer T. Sarli Dept/Date 23 June 94

Division/Section Head Cherrell Dept/Date 01/23/94

Results \_\_\_\_\_

Witness \_\_\_\_\_ Dept/Date \_\_\_\_\_  
(Safety Officer or Designee)

\* Must be signed by division/section safety officer and division/section head prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.



3. TESTING SYSTEM SCHEMATIC - HYDROSTATIC

1. M.A.B. WATER SUPPLY LINE  
MAX. PRESSURE 65 [psi]
2. WATER FLOW CAPACITY CONTROL  
SECTION "A - B"  $\frac{1}{8}$ " SCH 40 PIPE  
INSIDE DIA : 0.269"
3. METERING VALVE  $\frac{1}{4}$ " NPT  
PARKER 1/4-4M-V4LNT-3
4. PRESSURE GAUGE  
"WEISS" 0 TO 100 psi
5. RELIEF VALVE (WATER)  
SET PRESSURE 40 psig  
CAPACITY 18 GAL/min  
@ 10% OVERPRESSURE  
TELEDYNE-FARRIS TYPE 1850,  $1\frac{1}{2}$ "
6. BLEED VALVE  
DIMENSION " " HAS TO BE LARGER OR EQUAL 10 Ft  
FOR VACUUM TEST BUT MAY BE CLOSER THAN 10  
FOR HYDROSTATIC TEST.
7. FLEXIBLE HOSE  
 $\frac{1}{4}$ " , 400 psi RATING
8. WILDE OPTICAL  
LEVEL N2
9. CHECK VALVE  
 $\frac{3}{8}$ " NPT

• DETERMINE THE FLOW RATE IN  $\frac{1}{8}$ " PIPE, SECTION "A-B" (ITEM 2).  
GIVEN DATA: MAX. PRESSURE IN THE M.A.B. SUPPLY LINE = 65 [psig]  
INSIDE DIA OF THE "A-B" SECTION  
 $d = 0.269$ "

ASSUMED NO FRICTION IN THE PIPE.

$p = 65 \text{ psi} = 150 \text{ Ft of } H_2O$   
FROM BERNOULLI'S EQUATION:

$$\frac{v^2}{2g} = 150$$

$v$  - WATER VELOCITY IN THE PIPE  
 $g$  - GRAVITY ACCELERATION

$$v = \sqrt{150(2)} = 32.2$$

$$v = 98.28 \text{ Ft/sec}$$

FLOW CAPACITY:

$$Q = A \cdot v$$

$$A = \frac{\pi d^2}{4} = 0.00039 \text{ [Ft}^2\text{]}$$

$$Q = 0.0383 \left[ \frac{\text{Ft}^3}{\text{sec}} \right] = 17.2 \text{ GPM}$$

1.8M KTEV WINDOW HYDROSTATIC TEST

PARKER - METERING VALVE / TYPE:

1/4 - 4M - V4LN - B

Needle valve  
orifice  $\phi$  176  $\mu$

IN LINE  $C_v$  0.4

| $\Delta P$ |      |     |     |
|------------|------|-----|-----|
|            | psid |     |     |
|            | 10   | 50  | 100 |
|            |      |     | MPA |
|            | 1.27 |     |     |
|            | GPM  |     |     |
|            | 2.8  | 4.0 |     |

Hydro test 1.8 M. Kevlar Window

Hydro Test <sup>#1</sup> on 1.8 m. Kevlar Window

Date 6/27/94

Raw Data

| Time               | Scale reading | Pressure  | Change |
|--------------------|---------------|-----------|--------|
| 10:07 AM           | 13.748        | 0.0 lbs.  |        |
| 10:51 AM           | 10.832        | 5.0 lbs.  | 2.916  |
| 10:55 AM           | 9.735         | 10.0 lbs. | 1.097  |
| 10:59 AM           | 8.978         | 14.7 lbs. | 0.757  |
| 11:01 AM           | 8.846         | 16.0 lbs. | 0.132  |
| 11:04 AM           | 8.635         | 18.0 lbs. | 0.211  |
| 11:08 AM           | 8.413         | 20.0 lbs. | 0.222  |
| 11:09 AM           | 8.386         |           | 0.027  |
| 11:10 AM           | 8.227         | 22.0 lbs. | 0.159  |
| 11:12 AM           | 8.052         | 24.0 lbs. | 0.175  |
| 11:13 AM           | 7.892         | 26.0 lbs. | 0.160  |
| Failed before read |               | 28.0 lbs. |        |

5.856

Flange Reading 14.668  
 Flange Width 1.75  
 Total reading 16.418

Teflon foot= 0.335

| Total Distance with Teflon Foot |
|---------------------------------|
| 14.083                          |
| 11.167                          |
| 10.070                          |
| 9.313                           |
| 9.181                           |
| 8.970                           |
| 8.748                           |
| 8.721                           |
| 8.562                           |
| 8.387                           |
| 8.227                           |

Total change from 0 lbs. pressure to 26.0 lbs pressure was 5.856 inches.



\*All readings and measurements taken in inches.

## Second Hydro Test on 1.8 m. Kevlar Window

Date 7/18/94

### Raw Data

| Flange Reading | Time             | Scale reading | Pressure | Change |
|----------------|------------------|---------------|----------|--------|
| 14.188         | 10:30 AM         | 13.265        | 0        | 0.000  |
| 14.185         | 10:43 AM         | 10.460        | 5        | 2.805  |
| 14.181         | 10:49 AM         | 9.217         | 10       | 1.243  |
| 14.179         | 10:51 AM         | 8.483         | 14.7     | 0.734  |
| 14.178         | 10:56 AM         | 8.317         | 16       | 0.166  |
| 14.176         | 11:02 AM         | 8.093         | 18       | 0.224  |
| 14.174         | 11:08 AM         | 7.874         | 20       | 0.219  |
| 14.174         | 11:15 AM         | 7.678         | 22       | 0.196  |
| 14.171         | 11:27 AM         | 7.483         | 24       | 0.195  |
| 14.171         | 11:38 AM         | 7.309         | 26       | 0.174  |
|                | 11:50 AM         | 7.139         | 28       | 0.170  |
| 14.188         | approx. 11:50:10 | 7.089         | *        | 0.050  |

\* Reading just after Kevlar Broke

|                |        |
|----------------|--------|
| Flange Reading | 14.188 |
| Flange Width   | 1.75   |
| Total reading  | 15.938 |

Teflon foot= 0.335

| Pressure | Total Distance with Teflon Foot |
|----------|---------------------------------|
| 0        | 2.338                           |
| 5        | 5.143                           |
| 10       | 6.386                           |
| 14.7     | 7.120                           |
| 16       | 7.286                           |
| 18       | 7.510                           |
| 20       | 7.729                           |
| 22       | 7.925                           |
| 24       | 8.120                           |
| 26       | 8.294                           |
| 28       | 8.464                           |

Total change from 0 lbs. pressure to 28.0 lbs pressure was 6.126 inches.

R.L. Smith

\* All readings and measurements taken in inches.

### Third Hydro Test on 1.8 m. Kevlar Window

Date 8/1/94

| Scale Readings |        |        | Time     | Scale Reading | Pressure  | Change |
|----------------|--------|--------|----------|---------------|-----------|--------|
| A              | B      | C      |          |               |           |        |
| 14.219         | 14.195 | 14.210 | 10:31 AM | 13.139        | 0 PSIG    | 0.000  |
| 14.207         | 14.200 | 14.203 | 10:55 AM | 10.049        | 5 PSIG    | 3.090  |
| 14.199         | 14.206 | 14.205 | 11:10 AM | 9.038         | 10 PSIG   | 1.011  |
| 14.191         | 14.206 | 14.207 | 11:13 AM | 8.319         | 14.7 PSIG | 0.719  |
| 14.190         | 14.212 | 14.210 | 11:18 AM | 8.153         | 16 PSIG   | 0.166  |
| 14.187         | 14.214 | 14.210 | 11:23 AM | 7.935         | 18 PSIG   | 0.218  |
| 14.186         | 14.215 | 14.210 | 11:28 AM | 7.759         | 20 PSIG   | 0.176  |
| 14.184         | 14.218 | 14.212 | 11:34 AM | 7.591         | 22 PSIG   | 0.168  |
| 14.181         | 14.218 | 14.212 | 11:45 AM | 7.415         | 24 PSIG   | 0.176  |
| 14.207         | 14.191 | 14.196 | 11:49 AM | 7.364         | 2 PSIG    | 0.051  |

\* Kevlar failed, but Mylar held.

Average Flange Reading 14.208  
 Flange Width 1.75 Teflon foot= 0.335  
 Total reading 15.958

| Pressure Reading | Total Distance with Teflon Foot |
|------------------|---------------------------------|
| 0 PSIG           | 2.358                           |
| 5 PSIG           | 5.574                           |
| 10 PSIG          | 6.586                           |
| 14.7 PSIG        | 7.304                           |
| 16 PSIG          | 7.470                           |
| 18 PSIG          | 7.688                           |
| 20 PSIG          | 7.864                           |
| 22 PSIG          | 8.032                           |
| 24 PSIG          | 8.208                           |
| * 2 PSIG         | 8.259                           |

Total change from 0 lbs. pressure to 24.0 lbs pressure was 5.775

\* Kevlar failed, but Mylar held.

G.K. Adkins

\* All readings and measurements taken in inches.

### Fourth Hydro Test on 1.8 m. Kevlar Window

Date 8/23/94

| Scale Readings |        |        | Time    | Scale Reading | Pressure | Change |
|----------------|--------|--------|---------|---------------|----------|--------|
| A              | B      | C      |         |               |          |        |
| 14.168         | 14.154 | 14.188 | 1:25 PM | 13.543        | 0        | 0.000  |
| 14.170         | 14.159 | 14.180 | 1:49 PM | 10.316        | 5        | 3.227  |
| 14.173         | 14.161 | 14.169 | 1:55 PM | 9.158         | 10       | 1.158  |
| 14.174         | 14.163 | 14.161 | 2:04 PM | 8.399         | 14.7     | 0.759  |
| 14.174         | 14.165 | 14.158 | 2:07 PM | 8.223         | 16       | 0.176  |
| 14.175         | 14.165 | 14.155 | 2:10 PM | 7.992         | 18       | 0.231  |
| 14.176         | 14.167 | 14.152 | 2:12 PM | 7.807         | 20       | 0.185  |
| 14.176         | 14.167 | 14.149 | 2:16 PM | 7.616         | 22       | 0.191  |
| 14.177         | 14.168 | 14.147 | 2:20 PM | 7.43          | 24       | 0.186  |
| 14.175         | 14.169 | 14.143 | 2:27 PM | 7.249         | 26       | 0.181  |
| 14.179         | 14.168 | 14.141 | 2:34 PM | 7.085         | 28       | 0.164  |

Average Flange Reading 14.17  
 Flange Width 1.75 Teflon foot= 0.335  
 Total reading 15.92

| Pressure Reading | Total Distance with Teflon Foot |
|------------------|---------------------------------|
| 0                | 0.000                           |
| 5                | 3.562                           |
| 10               | 1.493                           |
| 15               | 1.094                           |
| 16               | 0.511                           |
| 18               | 0.566                           |
| 20               | 0.520                           |
| 22               | 0.526                           |
| 24               | 0.521                           |
| 26               | 0.516                           |
| 28               | 0.499                           |

Total change from 0 lbs. pressure to 28.0 lbs pressure was 6.458

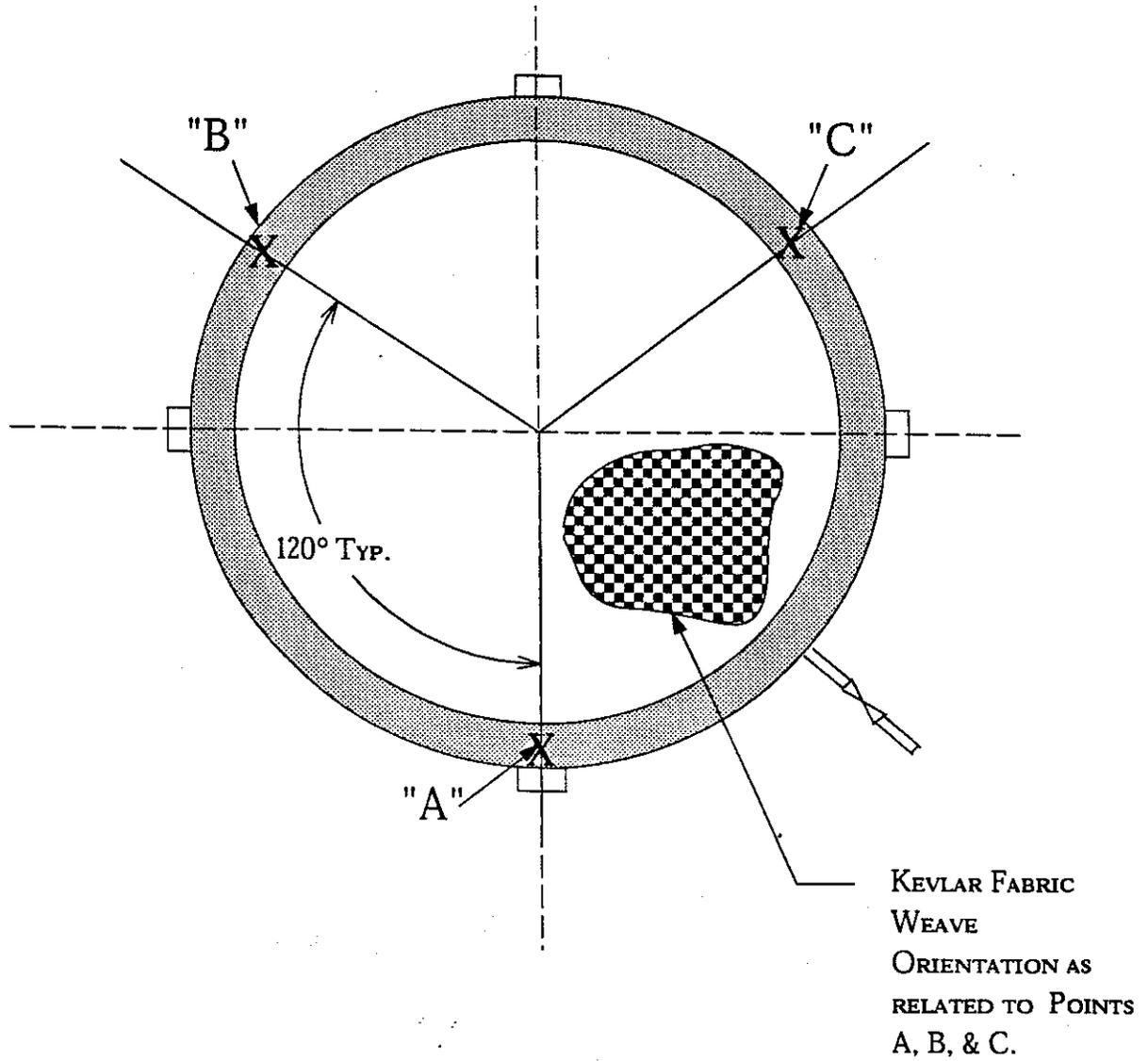
C Bradford  
 Revised: 8/29/94

\* All readings and measurements taken in inches.

# FOURTH HYDRO TEST KTEV VACUUM WINDOW

AUGUST 25, 1994

- 1 KEVLAR ORIENTATION
2. DEFLECTION OF THE FLANGE.



KTeV 1.8 m VACUUM WINDOW

PART C

1.8 m VACUUM WINDOW  
VACUUM PUNCTURE TEST



Fermilab

Date APRIL 18, 94

EXHIBIT B  
Pressure Testing Permit\*

VACUUM PUNCTURE TEST.

Type of Test:  Hydrostatic  Pneumatic  
Test Pressure: 14.7 <sup>NEGATIVE</sup> psig Maximum Allowable Working Pressure: 45 psig  
Items to be Tested 1.8m VACUUM WINDOW  
SEE DNG. 9220.332.MD-285394

Location of Test M.A.R. Date and Time APRIL 21, 94  
Hazards Involved RUPTURE OF THE WINDOW COMPONENTS  
WHAT MAY GENERATE ABNORMAL SOUND LEVEL. ROES: H  
OTHER HAZARDS RELATED TO TYPICAL INDUSTRIAL INSTALLATION

Safety Precautions Taken  
SEE SUBSECTION 1 OF "1.8m VACUUM WINDOW TESTING PROCEDURE FOR VACUUM AND HYDROSTATIC TESTS"

Special Conditions or Requirements TESTING PROCEDURE HAS TO BE CONS  
WITH: "KTEV 1.8m VACUUM WINDOW OVERVIEW OF TEST PROCEDURE" - PUNCTURE TEST.

Test Coordinator ANDREW SZYMULANSKI Dept/Date \_\_\_\_\_  
Division/Section Safety Officer J. Barlow Dept/Date 18 April 94  
Division/Section Head [Signature] Dept/Date 4/19/94

Results SEE: "RESULTS OF 1.8m VACUUM WINDOW PUNCTURE TEST"

Witness \_\_\_\_\_ Dept/Date \_\_\_\_\_  
(Safety Officer or Designee)

\*Must be signed by division/section safety officer and division/section head prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.

RESULTS OF THE 1.8M VACUUM  
WINDOW PUNCTURE TEST

- a) THE WINDOW MYLAR / KEVLAR SANDWICH WAS PUNCTURED BY AN ARROW, CAUSING SUDDEN RUPTURE OF THE COMPOSITE MATERIALS, AS PICTURED ON THE PHOTOGRAPH "FNAL 94-485-1" THE ARROW WAS DESIGNED IN A WAY TO CREATE A FULL PENETRATION INTO MYLAR / KEVLAR COMPOSITION.

THE FIXTURE TO WHICH THE WINDOW WAS BOLTED, WAS NOT ANCHORED TO THE FLOOR. SLIGHT DISLOCATION OF THE FIXTURE WAS NOTICED, AFTER IMPACT.

- b) KTeV VACUUM WINDOW ENGINEERING NOTE "WBS #'S 1.1.1.4 TO 1.1.1.9 ENGINEERING ANALYSIS REPORT (EAR) # 121 FAILURE ANALYSIS FOR 1.8M VACUUM WINDOW

KTeV By ANG LEE

DISCUSSES THE THEORETICAL ASPECTS OF THE TEST