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DEVELOPMENT OF A RELIABLE LINE
DISCONNECT FOR THE TRANSURANIUM
PROCESSING FACILITY

T. S. Mackey

OAK RIDGE NATIONAL LABORATORY

operated by

UNION CARBIDE CORPORATION

for the

U.S. ATOMIC ENERGY COMMISSION

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CHEMICAL TECHNOLOGY DIVISION

Unit Operations Section

DEVELOPMENT OF A RELIABLE LINE DISCONNECT FOR THE
TRANSURANIUM PROCESSING FACILITY

T. S. Mackey

Date Issued

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DEVELOPMENT OF A RELIABLE LINE DISCONNECT FOR THE
TRANSURANIUM PROCESSING FACILITY

T. S. Mackey

ABSTRACT

Reliable line disconnects are necessary to permit the remote replacement of process equipment in the Transuranium Processing Facility. Two disconnect designs were subjected to several severe tests in order to select the most suitable design.

These performance tests demonstrated the superiority of the surface-seal concept over that of the line seal-concept and the reliability of this seal when subjected to misalignment forces, corrosive solutions, rough handling and interchange of mating parts.

Tests of Hastelloy C disconnects after heat treatment demonstrated the necessity for joining the disconnect to the process tubing by means other than welding. Several leak-tight joints were made by external mechanical swaging, by external electrical swaging (by the "Magniform" process developed by the General Dynamics Corporation) and by internal rolling.

Hastelloy C disconnect samples machined to reasonable machine tolerance established the economic feasibility of the design.

1. INTRODUCTION

1.1 General Description of the Problem and the Two
Satisfactory Designs for Line Disconnects

The problem of maintaining the Transuranium processing equipment and ensuring a high degree of flexibility in equipment arrangement will be solved by removal of the entire equipment rack or the defective component. Quick acting fluid disconnects will be placed at strategic locations to permit the remote breaking of the various process lines necessary for the substitution of the new component.

The design criteria for the disconnect specifies metal-to-metal seats for sealing action without the use of gaskets or other loose parts that would interfere or make remote handling with manipulators difficult. Two designs satisfying the above requirements were developed, and test models of each performed satisfactorily.

The first design (Fig. 1B) provides a large sealing-surface area. This is accomplished by forcing the male cone by bolt loading into the female cone. Initial contact is made at the tip of the male cone. Contact along the entire length is accomplished by proper bolt loading. Repeated sealing action depends on the slight remaining flexibility of the male cone. The male cone absorbs the wear and will be made replaceable in case of leakage.

An additional design (Fig. 1A) was tested and proved satisfactory after several make and break cycles and also several thermal cycles. This design incorporates spring tension as a means of providing the proper unit stress at the sealing surfaces without undue deformation. The spring action was believed beneficial in providing uniform sealing action and also for avoiding excessive stress buildup during thermal cycling.

The present work consisted of subjecting the two designs to several severe tests in an attempt to isolate the strong and weak points of each and thereby select the most suitable design for the Transuranium Process service. The occurrence of leakage was determined by use of a helium leak detector. Leakage due to repeated closures, damage from rough handling, interchanged parts, misalignment, and other factors of importance to the application of disconnects in the Transuranium cubicles was tested.

1.2 Acknowledgments

The Transuranium disconnect clamp designs were worked out by E. J. Breeding of the Chemical Technology Division Process Design Section.

The initial disconnect designs were devised by W. E. Unger, of the Chemical Technology Division Process Design Section, and G. K. Ellis, formerly of the Chemical Technology Division Unit Operations Section.

P. P. Holz of the Reactor Division MSRE Development group contributed to the initial testing and development of the disconnect.

W. A. Walker of the Mechanical Division assisted in several phases of the disconnect test work.

J. N. Wheeler of the Engineering and Mechanical Division submitted several useful suggestions, including the use of the "Magniform" process for connecting the disconnect to the process tubing.

2. EXPERIMENTAL PROCEDURE

The disconnects were machined from type 304 stainless steel according to the drawing shown in Fig. 2. Samples with dimension A of 0.331 in. gave a cone-base thickness of approximately 0.048 in.; these were marked A. Samples with a cone-base thickness of 0.061 in. were marked B, and samples with a cone-base thickness of 0.073 in. were marked C.

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A. Line Seal

B. Surface Seal

Fig. 1. Seal Concepts for the Disconnect.

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For Sample A - $A = 0.331 \pm 0.001$
For Sample B - $A = 0.305 \pm 0.001$
For Sample C - $A = 0.281 \pm 0.001$

Fig. 2. Specifications for the Test Samples of the Disconnects.

This provided a range of flexibility in the male cones and, for a particular loading force, would provide a range of contact area.

A Consolidated Engineering Corporation helium leak detector, Model 24-101A, was used for leak testing. It was calibrated with a standard helium leak and gave at 0.01 μ pressure an over-all sensitivity of 1×10^{-8} std cc of helium per second. The leak-detection procedure was as follows: The disconnect was placed in the clamping device (Figs. 3 and 4) and then connected to the leak detector. The disconnect was then pumped down to 0.01 μ by the leak detector vacuum system. The disconnect assembly was then placed in a plastic bag to which helium was admitted continuously in order to provide an almost pure helium atmosphere. Leakage in excess of 1×10^{-8} std cc of helium per second was immediately registered on the leak detector. If no leakage was indicated, the closure was considered perfect. No attempt was made to measure the magnitude of the disconnect leakage; however, this would have been necessary in only a few cases because most tests indicated perfect seals.

3. TEST RESULTS

The description of the tests and results are as follows:

3.1 Test 1. Test of Leak Tightness and Repeatability of Closure

The first six disconnects were placed in the clamping device and tightened to 150 lb-in. of torque. No lubrication was used on the disconnect surfaces because it would have obscured the test results. Sample A-1 was distorted in an attempt to use a water graphite mixture. Sample A-5 was substituted for A-1. The results of the tests are as follows:

<u>Sample</u>	<u>No. of Cycles and Quality of Closure</u>
A-2	10, perfect
A-5	10, perfect
B-1	10, perfect
B-2	10, perfect
C-1	10, perfect
C-2	10, perfect

A set of six new disconnects were placed in the spring-loaded clamping device (Fig. 4), which gave approximately 125 lb of force on each disconnect. The results of the tests are as follows:

<u>Sample</u>	<u>No. of Cycles and Quality of Closure</u>
A-3	14, perfect
A-4	11, perfect, leakage on 12th cycle
B-3	9, perfect, leakage on 10th cycle
B-4	14, perfect
C-3	14, perfect
C-4	8, perfect, leakage on 9th cycle

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Fig. 3. Clamp for Performance Testing.

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Fig. 4. Spring-Loaded Gang Disconnect.

3.2 Test 2. Resistance to Progressive Corrosion

The disconnects were tested for corrosion resistance in the following manner: The disconnect was placed in the clamping mechanism (Fig. 5) and installed as part of a glass recirculation system. The system consisted of a 2-liter separating funnel and an air lift made of 1/2-in. glass tubing. The disconnect was installed between the separatory funnel and the air lift, using Teflon tubing unions. Hot aqua regia (2 M HCl and 5 M HNO₃ at 70°C) was then circulated until failure occurred in the disconnect. A total of 3 tests were made using samples A-1, B-10, and C-9 female, C-10 male, with a loading of 150 lb-in. of torque. An additional test was made using sample A-11 with spring loading. In all cases failure occurred at the point of tubing connection or failure of the tubing sidewall (Fig. 6). The disconnect seal surfaces suffered no surface attack and were still leaktight at the end of the test.

3.3 Test 3. Resistance to Rough Handling

These tests were made as follows: Six disconnects previously tested in test 1 were marked with a spring-loaded center punch first through thin brass shim stock. This gave craters with edges of approximately 0.001 in. in height. These were made at a distance of 1/16 in., 1/8 in., and 3/16 in. from the male disconnect shoulder. Leak tests were made first with only one mark, then with two, and finally with all three. The results are listed below:

Sample	<u>1/16 in.</u>	<u>1/16 and 1/8 in.</u>	<u>1/16, 1/8, and 3/16 in.</u>
A-2	perfect closure	perfect closure	perfect closure
A-5	perfect closure	perfect closure	perfect closure
B-1	perfect closure	perfect closure	perfect closure
B-2	perfect closure	perfect closure	perfect closure
C-1	perfect closure	perfect closure	perfect closure
C-2	perfect closure	perfect closure	perfect closure

The samples were then marked in the same manner except without the shim stock. This gave craters with an edge height of 0.002 in. to 0.003 in. These were then leak tested. The results are as follows:

Sample	<u>1/16 in.</u>	<u>1/16 and 1/8 in.</u>	<u>1/16, 1/8, and 3/16 in.</u>
A-2	perfect closure	perfect closure	perfect closure
A-5	perfect closure	perfect closure	perfect closure
B-1	perfect closure	perfect closure	perfect closure
B-2	perfect closure	perfect closure	leak
C-1	perfect closure	perfect closure	perfect closure
C-2	perfect closure	perfect closure	perfect closure

Three new disconnects were then marked as above with the spring-loaded center punch. Then each was placed in the clamping device and torque was applied until the leakage stopped. The results are as follows:

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Fig. 5. Clamp for Corrosion Testing.

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Fig. 6. Disconnect Corrosion-Test Samples.

A-8	Required 125 lb-in. of torque for perfect closure
B-8	Required 75 lb-in. of torque for perfect closure
C-8	Required 240 lb-in. of torque for perfect closure

3.4 Test 4. Interchangeability of Parts

The disconnect samples used in test 1 were rearranged according to the pattern shown below and checked with a closing force of 150 lb-in. of torque. Results are listed below:

<u>Male Half</u>	<u>Female Half</u>	<u>No. of Cycles with Perfect Closures</u>
A-2	B-2	10
B-2	A-2	10
C-2	B-1	10
B-1	C-2	10
C-1	A-5	10
A-5	C-1	10

3.5 Test 5. Effect of Misalignment on Sealing Ability

The disconnects were placed in the clamping arrangement (Fig. 3) with 0.040-in. shim stock, which produced approximately $1/2^\circ$ of misalignment. A clamping force of 150 lb-in. of torque was used on all disconnects. The results are as follows:

<u>Sample</u>	<u>No. of Cycles with Perfect Closures</u>
A-3	10
A-4	10
B-3	10
B-4	10
C-3	10
C-4	10

3.6 Test 6. Measurements of the Forces Required to Seal the Disconnect Properly

This test was designed to determine the force required to give a maximum area of contact in the seal surfaces. Samples A-7, B-7, and C-7 were placed in a hydraulic press and forced together gradually to provide force-versus-seating-depth measurements. A seating depth of 0.020 in. is required for complete surface contact of the disconnect. The results of the test are given in the form of a graph in Fig. 7. These forces correspond to approximately 10 lb-ft of torque used for the clamping arrangement shown in Fig. 3. In the spring-loaded manifold used in test 1, samples A-2 and A-5 were sealed approximately 0.006 in., samples B-1 and B-2 approximately 0.005 in., and samples C-1 and C-2 approximately 0.003 in.

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Fig. 7. Disconnect Seating Force vs Seating Depth

3.7 Test 7. Effect of Machine Tolerances on Disconnect Sealing Ability

This test was designed to determine whether a satisfactory disconnect could be manufactured with standard machine tolerances. The tolerances were set by personnel familiar with machine-shop limitations such that a further increase in tolerance would not result in appreciable decrease in disconnect machining cost. Six sets of disconnects were machined of Hastelloy C. The dimensions of the disconnects were held as precisely as possible to give the inner and outer tolerance limits. Three sets were machined to give the loosest fit possible and three to give the tightest fit possible as shown in Fig. 8. The actual measured dimensions of the sample disconnects were as follows:

Tight-Fit Samples

<u>Male Half</u>	<u>Female Half</u>
HC-7	HC-7
A = 0.419	E = 0.280
β = 0.043	β = 19°45'
C = 0.266	
α = 17°48'	
HC-9	HC-9
A = 0.419	E = 0.280
B = 0.046	β = 19°52'
C = 0.266	
α = 17°38'	
HC-10	HC-10
A = 0.419	E = 0.280
B = 0.051	β = 19°24'
C = 0.266	
α = 17°37'	

Loose-Fit Samples

<u>Male Half</u>	<u>Female Half</u>
HC-8	HC-8
A = 0.417	E = 0.282
B = 0.042	β = 20°19'
C = 0.264	
α = 18°8'	

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	Tight Fit	O - Tolerance	Loose Fit
A	0.419"	0.418"	0.417"
B	0.046"	0.045"	0.044"
C	0.266"	0.265"	0.264"
α	17°45'	18°	18°15'
D	0.415"	0.416"	0.417"
E	0.280"	0.281"	0.282"
β	19°45'	20°	20°15'

Fig. 8. Disconnect Test-Sample Tolerances

HC-11

$$A = 0.417$$

$$B = 0.044$$

$$C = 0.264$$

$$\alpha = 18^{\circ}5'$$

HC-11

$$E = 0.282$$

$$\beta = 20^{\circ}9'$$

HC-12

$$A = 0.417$$

$$B = 0.042$$

$$C = 0.264$$

$$\alpha = 18^{\circ}8'$$

HC-12

$$E = 0.282$$

$$\beta = 20^{\circ}5'$$

The Hastelloy C disconnects were then placed in the clamping arrangement (Fig. 9) and tightened to give a seating depth of 0.020 in. This corresponded to 45 lb-ft of torque. The disconnects were then tested for leaks with the helium leak detector. The results are as follows:

HC-7 10 perfect closures
 HC-9 first closure imperfect, then 9 perfect closures
 HC-10 imperfect closure due to scratch on female sealing surface
 HC-8 10 perfect closures
 HC-11 10 perfect closures
 HC-12 not tested

HC-7 male half	HC-8 female half	10 perfect closures
HC-8 male half	HC-7 female half	10 perfect closures
HC-9 male half	HC-10 female half	10 perfect closures
HC-10 male half	HC-9 female half	10 perfect closures

3.8 Test 8. Effect of Heat Treatment on the Sealing Capabilities for Hastelloy C Disconnects

Five sets of Hastelloy C disconnects were heat treated as follows: The disconnects were brought up to 2225°F in air, held at this temperature for 30 min and then quenched in water. The disconnects were then placed in the clamping device and helium leak tested. The results are as follows:

<u>Sample</u>	<u>Leak Rate</u>
HC-7	immeasurably high
HC-8	immeasurably high
HC-9	immeasurably high
HC-11	immeasurably high
HC-12	immeasurably high

Both surfaces were cleaned with fine emery cloth and then again leak tested. The results are as follows:

Fig. 9. TRU Facility Disconnect Clamp Design, Mark I.

<u>Sample</u>	<u>Leak Rate</u>
HC-7	immeasurably high
HC-8	immeasurably high
HC-9	immeasurably high
HC-11	immeasurably high
HC-12	immeasurably high

Two disconnect males were machined on the inside to give a thinner cross section which should have given better sealing. The disconnects were placed in clamping device and leak tested. The results are as follows:

<u>Sample</u>	<u>Leak Rate</u>
HC-11	immeasurably high
HC-12	immeasurably high

Measurements were made in heat-treated male cone sections. Heat treatment had produced 0.002-in. in diameter warpage. Female sections suffered a diameter warpage of approximately 0.001 in.

All female halves leaked when made up with a male half that had not been heat treated.

All male halves leaked when made up with a female half that had not been heat treated.

Disconnects HC-8 and HC-9 were remachined and then heat treated in an atmosphere of hydrogen. Both had immeasurably high leak rates.

3.9 Test 9. Test of Clamping Arrangement

A single-bolt clamping arrangement designed for use in the Trans-uranium Facility (Fig. 9) was tested for its sealing ability, using a 3/8-in. Hastelloy C disconnect. A perfect closure was obtained with a maximum of 390 lb-in. of bending moment applied to the disconnect. It was necessary to use 45 lb-ft of torque to obtain proper sealing of the disconnect.

An additional disconnect for 1/2-in. tubing was placed in the clamp and the retaining nut tightened. Bending of the closure bolt occurred before the disconnect was properly sealed. A new design was worked out to apply the additional force required in the larger disconnect sizes. This design is shown in Fig. 10.

3.10 Test 10. Test of Methods for Disconnect Tubing Attachment

Several mechanical methods for attaching the disconnect to the process tubing were tested. These include mechanically swaging the disconnect down on the connecting tubing, electrically swaging (Magni-form process) the disconnect down on the tubing, and internally rolling the tube into the disconnect. All three methods gave perfect seals,

To Close:

- A. Insert (7) Into Front (2).
- B. Insert Mating (6) From Top.
- C. Tighten (5) Clockwise on Stud (3) Compressing (4) to (1) & (8).
- D. Item (8) will Yield on Axis of (3), Rotating (1) Clockwise to Back of (6).
- E. Any Further Compressing Action Will be Transferred to Clamping (6) & (7), Sealing Joint.
- F. Any Bending of (3) will be Arrested by Shoulder of (2).

To Open: (Arrows)

- (A) Loosen (5) Counter Clockwise.
- (B) (8) will Return to its Normal Shape, Lifting and Rotating (1) Free of (6), Counter Clockwise.
- (C) Raise (6) out of (2).
- (D) Raise (7) $1/16$ " & Remove Thru Front of (2).

- 1 SWING CLAMP
- 2 BLOCK
- 3 STUD BOLT
- 4 WASHER
- 5 NUT
- 6 FEMALE DISCONNECT
- 7 MALE DISCONNECT
- 8 EXTENSION SPRING

Fig. 10. TRU Facility Disconnect Clamp Design, Mark II.

with the exception of the male section of the disconnect that was electrically swaged. However, minor design changes might give 100% closure with this process. Samples of mechanically swaged disconnects are shown as Fig. 11A.

An additional disconnect concept has been devised in which the Hastelloy C process tubing is swaged with a coining die to produce the cone-seating surfaces. Three sample disconnects produced in this manner are shown in Fig. 11B.

4. CONCLUSIONS

Tests 1 and 3 demonstrated that, under most conditions, a surface-type seal is superior to the line-type seal which is accomplished with light spring tension. The force required for sealing the disconnects in test 3 far surpasses that which would be available with the 130-lb springs. If the spring force is increased to give closure with roughened cone surfaces, then it is no longer a line-contact seal but becomes an area seal. Thus, in reality, one is a variation of the other, and the selection becomes one of closing force.

In test 2 the corrosion pattern of the disconnect is such that the inside diameter of the disconnect is dissolved away before the sealing surface of the disconnect is attached. Therefore, if the disconnect cone base is thicker than the connecting process tubing one could expect the tubing to fail first. Design C in Fig. 2 was chosen for this reason and used for the Hastelloy C disconnects in test 7.

Test 4 proved that the disconnect parts are interchangeable and that it will not be necessary to remove the disconnects from the defective equipment component to use on the substitute. This is a distinct advantage because it would be difficult to decontaminate the used disconnects to a point which would permit reinstallation.

Tests 5 and 9 demonstrated that even though misalignment and misaligning forces exist in the process lines, a leaktight closure can still be expected.

Test 6 was used to measure the actual force necessary to seat the disconnect 0.020 in. Since it will not be possible to translate this force into torque measurements because of the large number of variables, it will be necessary to make torque-requirement measurements when the prototype disconnect and clamping devices are available from the manufacturer.

Test 7 demonstrated that the disconnects can be fabricated with standard-type machine tolerances and still function reliably.

Test 8 established the necessity for developing a means other than welding for fastening the Hastelloy C disconnects to the process tubing.

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Fig. 11. Swaged Joints and Disconnects.

Test 10 proved that mechanically connecting the Hastelloy C disconnects to the process line was feasible thus eliminating welding and heat treatment procedures.

5. RECOMMENDATIONS

The performance tests of the Transuranium disconnect proved it to be a very reliable type of closure even under very severe operating conditions. The recommended design and tolerances are given in Fig. 12, and these should be followed when the disconnect is fabricated of Hastelloy C or stainless steel. The use of other materials will dictate a study of the mechanical properties of those materials, including the surface-galling properties.

Future work should be directed toward adapting this design to tantalum or Zircaloy-2, selecting the most suitable means of attaching the disconnect to the process tubing, and evaluating the additional disconnect design proposed in test 10.

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Fig. 12. Recommended Design and Tolerances for Disconnects.

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