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EVALUATION OF TEFLON HOSE

for

Hanford Reactor Service

AUTHOR

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HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

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EVALUATION OF TEFLON HOSE

for

Hanford Reactor Service

AUTHOR

E. R. Rudock

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for
Hanford Reactor Service

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By Authority of CG-PR-2
DS Lewis 8-31-92
By PM Eick 4-26-94
Verified By J. N. L. 4-27-94

by
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Reactor Design and Development Unit
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Sept, 1955

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

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ABSTRACT

*Teflon hose was tested and evaluated for its usability as an integral piping component of a Hanford reactor process tube cooling system.

A satisfactory process tube connector design, fabricated from *Teflon hose, was developed for the replacement of the existing 100-K reactor aluminum connectors.

*duPont Co. trade mark for its tetrefluoroethylene resin

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EVALUATION OF *TEFLON HOSE - FOR HANFORD REACTOR SERVICE

INTRODUCTION

The safe operation of a Hanford reactor depends on the continuous and reliable supply of cooling water to the reactor process tubes. The full extent of damage to the reactor and possible injury to operating personnel, resulting from a sudden loss of coolant, is unknown and beyond the scope of estimation and monetary evaluation.

The process tube is dependent upon a tubing connector assembly to conduct the inlet supply of cooling water. An aluminum connector assembly is now being used for the 100-K reactor process tubes. A replacement connector is required that will ensure against operational failure.⁽¹⁾

PURPOSE

This report evaluates the qualifications of a connector assembly made from wire reinforced Teflon tubing for inlet process tube service. The objective of all tests performed on the hose material was to expose and evaluate the mechanical weaknesses or hose limitations which would eliminate a Teflon connector as a satisfactory design.

CONCLUSIONS

A new connector assembly design must satisfy all reactor safety, operational, and maintenance requirements to be acceptable for on-reactor usage. Research and development work on several designs ⁽²⁾ for an inlet header to process tube connector has lead to consideration of an assembly that is made from a braid covered Teflon hose. All testing necessary to evaluate the hose for inlet process tube service has been completed. Conclusions resulting from the test program are:

1. A connector assembly made of Teflon is acceptable for inlet process tube service.
2. A braid covered Teflon hose has unlimited cycle life with respect to Hanford front-face service.

*duPont Co. trademark for its tetrafluoroethylene resin

- (1) Elder, B. R., and S. B. Bush, HW-33490, October 21, 1954 (Secret); p.2
- (2) Mansius, C. A., and J. R. Spink, Preliminary Report - 304 Stainless Steel Connectors, May 23, 1955. (Unclassified)

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3. Designed service temperature and pressure of the hose assembly is over three times the service requirements for a Hanford inlet connector.
4. The hose is capable of withstanding very rough abuse and mishandling with no apparent effect on cycle life or pressure strength. Burst pressures on all assemblies after severe kinking, twisting, and cycling were over 4,400 psi.
5. The Teflon will withstand front-face radiation levels indefinitely. (3)
6. The "Flexibility" of the assembly can also be considered a disadvantage since it is susceptible to easy kinking and twisting. The use of the hose would require care in handling. The hose is not damaged by kinking, but such usage is not a recommended installation practice.
7. A split or puncture in the Teflon liner would not seriously affect water flow into a process tube since the outer braid will retain the main flow path.
8. No information is available, nor have tests been completed at Hanford, to date, of the "long-period" effects on Teflon tubing, subject to high water velocities or long periods of cavitation.

RECOMMENDATIONS

It is recommended:

1. A Teflon hose assembly made according to the General Electric Company Drawing H-1-21974, (See Figure XIV), be used as a replacement for the existing 100-K reactor connectors.
2. Fabrication specifications to be prepared and negotiations for their purchase begun at once with the manufacturer. The approximate unit cost for this assembly will be \$28. 7,000 assemblies (\$196,000) will be required. This quantity includes construction and operational spares. The manufacturer would need four months to complete an order of this quantity.
3. Additional research and test work be performed with Teflon hose. Testing would be directed towards evaluation of high velocity water and cavitation effects on the hose liner and end fittings. A failure resulting from such effects would not impair reactor safety since the mode of failure would not result in sudden complete loss of cooling water to the process tube. Four to six months testing time and two engineer-man-months manpower would be needed for accelerated type tests to obtain this information.

(3)Cooke, J. P., Production Test No. 103-503-S1- Exposure of Elastomers to Pile Effluent and Effects of Radiation, HW-37255, July 25, 1955 (Official Use Only)

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DISCUSSION

The first prototype Teflon hose assemblies purchased were for 105-C rear-face connectors. These connectors were a straight length, single braid design. Two of these connectors were installed on the rear-face of 105-C during the month of November, 1954 under Production Test No. 105-585-A, HWC-33004.

One of the connectors was removed during the rear-face connector replacement program recently completed at C Area. The reason for its removal and its present location has not been verified to date. The remaining connector is still installed and was examined June 3, 1955, during a short outage. This connector appears to be in good condition and is scheduled for removal and further testing during the next scheduled outage.

Burst pressure data indicates that on single braided assemblies, the swagged end fitting will not blow-off prior to rupture of the tube wall, while the addition of the second outer braid results in a hose assembly that has a higher burst pressure but is more susceptible to end fitting blow-off. The second outer braid was added to the tubing to permit the hose to take a smaller bend radius without flattening.

The results of the cavitation test are not conclusive since the swagged collar leakage at 5,600 psi could have been caused by either the cavitation service or by the 100,000 cycle life test. More testing of this type should be completed.

The most unique feature of the hose is the Teflon lining. The characteristic property of Teflon is its chemical inertness. It is unaffected by any known chemical compound except the molten alkali metals and fluorene at elevated temperatures. Because of this inertness, it appears, from all known tests to date, to be ageless or completely unaffected by any oxidizing reaction. The E. I. duPont Co. has just completed their tenth year of exposure tests on Teflon samples weathering on the coast of Florida. Their report indicates no change in chemical or physical properties.

CONNECTOR DESCRIPTION

The connector assembly is made from high pressure, high temperature aircraft flexible hose rated at 1,000 psi operating pressure and 5,000 psi burst pressure. The liner of the hose is made of 7/8" I.D. "Fluoroflex-T-Teflon" tubing which is a compounded Teflon material. The compounding process was developed by the Resistoflex Co., Belleville, New Jersey. The hose liner is covered by a stainless steel wire braid sheathing.

The end fittings are designed with a 37° coned seat and swivel type nut. The 37° seat is machined in the nipple which is inserted into the end of the hose. The hose is permanently attached to the nipple by an outer collar or socket which is threaded to the nipple and then swagged down in O.D., compressing the outer braid and nipple. The outside surface of the nipple and the inside surface of the collar are serrated to increase the grip efficiency of the end fittings. See Figure XIV.

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Five basic connector designs have been tested. The descriptions are as follows:

1. A single outer braid straight hose approximately 12 inches long with straight end fittings. This design was a prototype for the rear-face of 105-C.
2. A double outer braid preformed hose. The hose was shaped into a 180° return bend of 6" diameter with straight end fittings. This design is a prototype for project CG-558 - "Old Area" nozzle assemblies. See Figures IV and XV.
3. A double outer braid hose preformed to the same shape as the three-bend metal connector developed for 100-K front-face nozzle assembly. The assembly had straight end fittings. See Figure V.
4. A double outer braid straight length hose with straight end fittings. This design was developed for 100-K front-face nozzle assemblies. This connector is installed by bending into a 180° bend from the nozzle to the second header fitting to the right of the nozzle on the header below. See Figure VI.
5. A double outer braid straight length of hose with 45° elbow end fittings. This connector was a 100-K prototype and is installed in the same position as the existing aluminum tubing connectors. See Figures VII, VIII and IX.

TEST PROCEDURES AND RESULTS

1. Cycling Test: The Mechanical Development Group of the Pile Tech. Sub-Section has installed a nine tube cycling machine in the 189-D Bldg., 100-D Area. The nine tubes are exact duplicates of an inlet-face header and nozzle assembly.

The length of cycle stroke, pressure and lattice spacing of each tube is independently variable. A complete cycle on the machine simulates a process tube thermal expansion cycle that takes place during a Pile start-up and shut-down cycle.

A counter records the number of strokes given to each tube. Upon loss of hydraulic pressure in a tube, the hydraulic cylinder which provides tube stroke power is automatically shut off. Nine different connectors, six of which had received previous treatment as described in following test descriptions, have been cycled. All stroke lengths have been 1-1/4" and at pressures of 300 psi and 600 psi. All assemblies cycled over 80,000 cycles -- no failures.

Five of the connectors were 100-K Area prototypes, two were "Old Area" prototypes, and two were 105-C rear-face prototypes.

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2. Tensile Load: Three straight 100-K type connectors were tensile tested at the Mechanical-Physical Properties Laboratory, 300 Area. The hose end fittings were gripped by the jaws of the tensile testing machine and a tensile load applied until failure of inner braid and Teflon tube. The loads for failure were (1) 2,960 lbs., (2) 2,900 lbs., (3) 3,200 lbs. The hose did not pull out of end fittings.
3. Braid Damage: A CG-558 hose assembly was installed on the 108-D Bldg. process tube flow mock-up. Header pressure was set at 500 psi giving a tube flow of 39 gpm. Successive strands of wire braid were cut with a hack saw, wire cutters, and pliers circumferentially around the hose until a blow-out rupture of the inner Teflon tube occurred. Approximately 80% of braid required cutting prior to rupture, resulting in approximately 60% loss of flow. Thirteen gallons per minute continued to flow into the process tube. See Figure X.

This test was duplicated with a preformed "K" connector with the following exception: the hose was pierced with an ice pick, resulting in the loss of two gal/min.

4. Rough Handling and Abuse: A single braid straight "C" assembly was bent back upon itself (kinked) in six different places along the hose, hammered flat over approximately 2" of length, rotated 90° and hammered flat over another 2" of length approximately 1" from the previous hammered section. This was continued over the full length of the assembly and then installed on the cycling machine. Cycling at 1-1/4" stroke for 62,000 cycles caused no failure. The hose was then ruptured at a burst pressure of 4,400 psi.

The above test was duplicated on a double braided "K" - 45° end fitting connector. After cycling over 100,000 cycles, the hose was ruptured at 6,000 psi, with an end fitting blow off.

5. Twist, Cycle and Flow: A preformed 100-K connector was assembled on tube mock-up cycling machine. The nozzle adapter was backed out two threads, the hose nut tightened down until nut friction caused unrestrained twisting. Nut was twisted until adapter shouldered on nozzle -- two full twists at 14 ft. lb. torque.

Assembly was cycled 100,435 cycles at 1-1/4" stroke, 600 psi, no failure.

Following cycle test, assembly was mocked-up in the 108-D flow laboratory with the following results:

Untwisted Hose

Tube Flow	- 44.4 gpm
Header Pressure	- 330 psi
Venturi Throat Pressure	- 177 psi

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Twisted Hose (2 twists)

Tube Flow	- 2.2 gpm
Header Pressure	- 330 psi
Venturi Throat Pressure	- 320 psi

The hose was then ruptured at - 6,400 psi

The above tests were duplicated with a 45° end fitting assembly, with a 180° twist applied at venturi adapter.

Cycles -- 89,544, 1-1/4" stroke - 600 psi -- no failure.

Flow -- twisted 180°

Tube Flow	- 4.4 gpm
Header Pressure	- 325 psi
Venturi Throat Pressure	- 314 psi
Burst Pressure	- 6200 psi

Photographs of these two installations will be found on Figures XI and XII.

6. Effect of Kinks on Panellit: An undamaged 45° end fitting connector was mocked-up in the 189-D Bldg., Heat Transfer Group, Pile Tech. Sub-Section Flow Lab. Header, venturi throat, and venturi inlet pressures were recorded for four different flow conditions to obtain system curves of pressure versus flow.

An identical connector was kinked in five different locations along the hose and then installed. Pressures and flow were recorded. The connector was then removed and reinked and twisted, and again installed. The above was duplicated eight different times for four different flow conditions, each time removing the connector and applying severe kinks and twists.

The plotted results of the above flow tests show no effect on Panellit (venturi-throat) or other system curves. A graph of these curves and photographs of the twisted hose before and after installation will be found on pages 14, 15, and 16, respectively. See Figures I, II and III.

The twisted hose was then removed and cycled at 1-1/4" stroke, 300 psi for 101,300 cycles with no failure. The hose was failed at 6,200 psi burst pressure, by an end fitting blow-off.

7. Short Term Cavitation Test: An undamaged "K" 45° assembly was installed on an empty process tube mock-up in the 189-D flow lab.

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Severe cavitation was developed in the connector with a header pressure of 500 psi, negative venturi throat pressure, and tube flow of 84 gpm. This assembly was allowed to cavitate for four hours. No detectable heating of hose outer braid was observed, as was experienced when a neoprene hose assembly was previously subjected to the same test.

The connector was then removed and cycled at 1-1/4" stroke, 100,000 cycles, 300 psi -- no failure. The hose failed by leaking around the swagged collar at 5,600 psi while attempting to establish a burst pressure.

8. Burst Pressure Tests: The following is an outline of all final burst pressure tests:

Single Braid - "C" Type

<u>Hose No.</u>	<u>Previous Treatment</u>	<u>Type Failure</u>	<u>Burst Pressure</u>
1	Rough handling and cycling	Tube rupture	4,400 psi
2	Cycling	Tube rupture	4,600 psi
3	None	Tube rupture	4,500 psi
4	None	Tube rupture	5,000 psi

Double Braid - 45° "K" Type

1	None	Tube rupture	6,800 psi
2	None	Blow-off	6,000 psi
3	Rough handling and cycling	Blow-off	6,000 psi
4	Twist-flow and cycling	Blow-off	6,200 psi
5	Kinks-Panellit & cycling	Blow-off	6,200 psi
6	Cavitation and cycling	Leakage	5,600 psi

Double Braid - Straight "K" Type

1	None	Blow-off	6,000 psi
2	Twist-flow and cycling	Tube rupture	6,400 psi

A photograph of a tube rupture failure of a 45° "K" type assembly is shown on Figure XIII.

9. Fitting Torque: Wrench torques were applied up to 250 ft. lbs. on the straight "K" type assembly, which has 1/8" seats and carbon steel nuts; and on a 45° "K" type, which has aluminum seats and aluminum nuts.

Between 200 and 250 ft. lbs., the present aluminum nozzle adapter began to neck-down in ID. This occurred when torquing with both types of connector end fittings. No dishing of adapter bevel developed.

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The aluminum elbow seat enlarged slightly in I.D. at a torque of 250 ft. lbs. This did not hamper the turning of the swivel nut.

No detectable damage occurred to the stainless steel seat at 250 ft. lbs.

10. Installation: No apparent difficulty is encountered during installation other than a tendency to twist hose at final seating if nozzle or venturi adapter is not tight. This would not be detrimental to cycle life, but does not represent good installation practice. The end fittings are supplied with wrench flats behind the swivel nut which may be used to restrain rotation. A wrench may also be used on the adapters to restrain rotation. In both cases, this would require using two wrenches when applying the final torque (AN Specifications recommend 62 ft. lbs. maximum). The straight hose has more tendency to twist than a 45° assembly.

ACKNOWLEDGMENT

The author wishes to acknowledge his indebtedness to the Pile Technology Sub-Section, Mechanical Development Group and the Mechanical-Physical Properties Laboratory, 300 Area, whose help and co-operation enabled this test program to be completed in the very short and critical time schedule enforced. Acknowledgment is also given to the E. I. duPont Company and to Mr. C. A. Sperati, an authority on the physical properties of Teflon, for the information they have so freely given.

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APPENDIX

Figure I	Performance Curve - Effects of Kinks
Figure II	Kinked Hose Installed on 189-D Bldg. Flow Lab Mock Up
Figure III	Twisted Hose before Installation
Figure IV	CG-558 - Prototype Installed on Flow Lab Mock Up
Figure V	100-K Prototype - Preformed with Straight End Fittings
Figure VI	100-K Prototype - Straight End Fittings
Figure VII	100-K Prototype - 45° End Fittings
Figure VIII	100-K Prototype - 45° End Fittings - Front Elevation View
Figure IX	100-K Prototype - 45° End Fittings - Top Plan View
Figure X	CG-558 Prototype - Braid Damage
Figure XI	100-K Prototype - Preformed with Straight End Fittings - Twisted
Figure XII	100-K Prototype - 45° Ends - Twisted
Figure XIII	100-K Prototype - 45° Ends - Burst Rupture
Figure XIV	Detail Drawing of 100-K Connector
Figure XV	Detail Drawing of Project CG-558 Connector

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EFFECT OF KINKS ON PANELLIT PRESSURE
and
TUBE FLOW

FIGURE 1

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FIGURE 1

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FIGURE III

FIGURE IV

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FIGURE V

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FIGURE VI

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FIGURE VII

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FIGURE VIII

FIGURE IX

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FIGURE XIII

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Figure X.D

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Figure Y.IV

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NOTES

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 (ALLIED RESEARCH
 PRODUCTS) OR
 APPROVED EQUIVALENT
 ASSEMBLY PART 3 - BRONZE-IRIDITE #3
 (ALLIED RESEARCH
 PRODUCTS) OR APPROVED
 EQUIVALENT.
PT.NO	AREA	A
1	B, D, F	3 ± 1
18.8
2	D, E, H	3 ± 1

PT.NO	AREA	A
1	B, D, F	$1 \frac{3}{8}$
2	DR, H	$3 \frac{3}{8}$
3	C	$2 \frac{3}{8}$

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Figure IV

SOCKET MATL. - STEEL, AMS 6322 (SAB 8740) CADMIUM PLATE
PER AMS 2400-5 MIN. OUTSIDE, PER AMS 2400-1 MIN. INSIDE
OR SST., AMS 5640 (TYPE 303)
NIPPLE MATL. - SST., AMS 5639 (TYPE 304) OR AMS 5647 (TYPE 304L)
NUT MATL. - STEEL, AMS 5024 (SAB 1137) CADMIUM PLATE
PER AMS 2400-5 MIN. OUTSIDE, PER AMS 2400-1 MIN.
INSIDE, OR SST. AMS 5640 (TYPE 303)
OR SST. AMS 5647 (TYPE 304L)

NOTES: (CONT)

2. CHECKING FIXTURE SHALL BE USED TO CHECK THE 6 1/2" O.D. DIM.,
THE 'A' DIM., & THE 6 1/2" MAX OVERALL DIM.
WHILE ON FIXTURE, NUTS SHALL BE FREE TO TURN BY HAND & NO
PART OF HOSE SHALL BE KINKED OR FLATTENED FROM BENDING
STRAIN. FIXTURE END CONNECTORS SHALL HAVE MIN. OF TWO THREADS

3	ADDED MATL SPECS FOR NUT NIPPLE & SOCKET 11.474	JEB 3-13-86	REV.	DATE	BY	DATE
2	1 WAS 5639 304 C. ADDED NOTE 2. WAS 14X R. 11.404	FIS 11-15-85	REV.	DATE	BY	DATE
1	ADDED NOTE 2 R. 11.366	FIS 11-10-85	REV.	DATE	BY	DATE
NO.	DESCRIPTION	REV. BY	DATE	APP. BY	DATE	DATE
REVISIONS						
APPROVALS						
SCALE: NONE						
DRAWN: [Signature] DATE 7/1/55						
CHECKED: [Signature] DATE 11-1-55						
ISSUED: [Signature] DATE 11-1-55						
DES. ENG. [Signature] DATE 11-1-55						
ENGINEER REQUEST NO. 11 300						
PROJECT NO. 03-558						
NO. 03-600						

U. S. ATOMIC ENERGY COMMISSION
HANFORD WORKS
GENERAL ELECTRIC

FLEXIBLE CONNECTOR ASS'M.

DRAWING TITLE
REFERENCE DRAWINGS

NONE
CLASSIFICATION

PROJECT TITLE
REACTOR MODIFICATION

BLDG. REF. NO. DWG. NO. H-15351 SHEET NO. SHEETS

UNCLASSIFIED

AIM

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Silver Spring, Maryland 20910

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Centimeter

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BY APPLIED IMAGE, INC.

**DATE
FILMED**

11/29/94

END