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A Division of North American Aviation, Inc.

NAA-SR-MEMO 8708

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ATOMICS INTERNATIONAL A Division of North American Aviation, Inc.		NAA-SR-MEMO TDR NO. 8708		APPROVALS	
TECHNICAL DATA RECORD		PAGE 1 OF 7		Ja Hagel	
AUTHOR S. L. Shulman <i>SLS</i>		DEPT & GROUP NO. 726-61		DATE 7-10-63	
TITLE Croloy Boiler Evaluation		GO NO. 7562		S/A NO. 2220 TWR	
PROGRAM SNAP-II		SUBACCOUNT TITLE PCS Design and Development		SECURITY CLASSIFICATION	
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				DATE	
				<i>St. St. Zelen</i> <i>8 July 63</i>	
STATEMENT OF PROBLEM		Evaluate the use of Croloy as the SNAP-II Boiler Material			
ABSTRACT:		The use of Croloy in the SNAP II boiler was investigated. A program to develop a Croloy boiler using a hydrogen diffusion barrier was presented.			

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I. INTRODUCTION

Recently, there have been suggestions from several sources that Croloy (9% Cr, 1% Mo, 1/2% Si) be used in the 5C boiler in place of existing materials. The suggestions are actually partially in conflict with each other and require closer study.

The suggestions, which will be discussed later in the letter are basically as follows:

- 1) Make the inner and outer shells of the boiler of Croloy and leave the rest of the design unaltered. This would allow hydrogen in the NaK system to diffuse to space at greater rate than is currently possible.
- 2) Make the entire boiler from Croloy. This would be done because mercury is less corrosive to Croloy than to the current material, Haynes 25. This would also eliminate the thermal stresses which occur in the current design because of the use of dissimilar metals.

These suggestions will now be discussed in detail along with their possible ramifications.

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A. Stress Considerations

A TDR (as yet unreleased) has been written, by M. Weisman, which investigates the structural problems associated with the use of Croloy, in the 5C boiler. The configurations studied were:

- 1) Boiler shell, tube support and inner can of Croloy and the rest of the boiler unaltered.
- 2) The entire boiler fabricated from Croloy.

The results of this study follow:

Proposal 1. This proposal introduces a small problem in the area of the tube sheet. The design is inadequate as it currently stands.

Proposal 2. This proposal eliminates all thermal stress problems since the proposal is for a one material boiler.

These conclusions are elaborated upon in the referenced TDR and so further interest in the above problems should be directed to that document.

B. Hydrogen Permeability

A problem in the SNAP II system is the accumulation of hydrogen in the R/C. The hydrogen, being a non-condensable, lowers the efficiency of the R/C.

Hydrogen originates in the nuclear reactor where it enters the NaK coolant stream. It is then transferred to the mercury stream by diffusion from the NaK stream through the boiler tubes. The hydrogen permeability of the boiler tubes therefore controls the rate of hydrogen diffusion from the NaK to the mercury.

Haynes 25, which is currently used in the boiler tubes, has a lower hydrogen permeability than Croloy. This means that, Croloy is not as attractive a boiler tube material as Haynes 25 from the standpoint of hydrogen diffusion.

The problem of an increased amount of hydrogen in the mercury system can be remedied by several methods. Some of these include:

- 1) Use of a hydrogen getterer
- 2) Use of high permeability materials in other parts of the mercury system to allow hydrogen to escape.
- 3) Enlarge the R/C to allow satisfactory operation at reduced efficiency.

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Because of the high hydrogen permeability of Croloy, it has been suggested that Croloy be used as the material for the inner and outer cans of the boiler. This would allow hydrogen to diffuse from the NaK side of the boiler to the vacuum of space. With this method, the inner can of the boiler might be vented to space to allow the hydrogen to escape.

Calculations have shown that Proposal 1 will result in about a 25% decrease of hydrogen in the R/C. Proposal 2 will result in a two to three times increase of hydrogen in the R/C.

Thus, from the standpoint of hydrogen permeability, the best configuration is a boiler with a Croloy outer and inner shell and Haynes 25 tubes (Proposal 1).

C. Material Considerations (Corrosion and Joining)

The change from the current boiler materials to a partially or completely Croloy boiler appears initially to be a change for the better from a corrosion standpoint. Corrosion studies at TRW have shown that the corrosion products formed by mercury contacting Croloy are only 60% of those for mercury contacting Haynes 25.

There are several potential problem areas worthy of investigation if a Croloy boiler is to be used. These are

- 1) a check of Croloy compatibility with the rest of the materials in the system
- 2) problems of joining Croloy to 316 stainless steel
- 3) problems of joining Croloy to other materials in the system.

In summary, from a standpoint of corrosion, Croloy appears to be a good choice as a material for the whole boiler (Proposal 2).

D. Thermal Performance of 5C Croloy Boiler

The present 5C boiler design uses mercury tubes of Haynes 25. This material has a thermal conductivity of approximately 13 Btu-ft/Hr-ft²-°F at 1200 °F. The thermal conductivity of Croloy at 1200 °F has not been published in the literature. However, at 212 °F, the thermal conductivity of Croloy is reported as 15 Btu-ft/Hr-ft²-°F. Eckert and Drake (p. 497) show the thermal conductivity of 10% Cr steel to vary from 18 at 212 °F to 16 Btu-ft/Hr-ft²-°F at 1112 °F. Since Croloy is a 9% Cr steel,

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we can expect the same type of temperature dependance and so a value around 13 Btu-ft/Hr-ft²-°F is probably valid.

The heat transfer rate, for the boiler is a function of the surface finish and thermal conductivity. In all probability, there is little difference between the surface finish of a Croloy tube or a Haynes 25 tube and so this effect should be negligible.

Since the thermal conductivities of Croloy and Haynes 25 are about equal at 1200 °F, and a stress analysis has shown that no change in tube wall thickness is necessary, the temperature drop through the tube wall will be the same in either case. This means that the heat transfer characteristics of a Croloy boiler should not change.

E. Fabrication Problems

The major fabrication problem, associated with producing a Croloy (tubed) boiler, is in winding the boiler tubing on the mandrel. The current mandrel was sized by a trial and error method to produce the proper dimensioned tube coil with Haynes 25. Should a decision be reached to use Croloy as the tube material, in all probability a new mandrel will have to be sized and machined. On the basis of the cost of the current mandrel, it will cost about \$20,000 to develop and machine a mandrel for use with Croloy. The time required to develop and machine the new mandrel can be expected to be about one month.

Should any configuration other than all Croloy be decided upon, several design changes, as discussed in the section "Stress Considerations", will have to be made.

F. Summary and Recommendations

Table I presents a summary of this study. The table shows that Proposal 1 has an advantage on the basis of hydrogen diffusion considerations and Proposal 2 has an advantage on the basis of mercury corrosion and stress considerations.

Neither of the proposals are completely acceptable by all criteria. Nevertheless, the Croloy boiler does have advantages worth investigating. Any plans to pursue this work however, should not compromise the compact boiler development. The compact boiler (Model 5C) has already proven its suitability for the flight system and should continue to be the basic flight design. In the meantime, a limited Croloy boiler program should be initiated to establish fabrication techniques, performance capabilities and structural integrity.

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I suggest that an all Croloy boiler, with a hydrogen diffusion barrier on the NaK side be developed. This boiler would be acceptable by all criteria of this study.

I suggest the following program:

- 1) Develop hydrogen barrier to be used on NaK side of tubes.
(AI or TRW proprietary processes)
 - a) Hydrogen permeability experiments
 - b) Compatibility with NaK
- 2) Develop fabrication techniques and build boiler
 - a) Joining techniques to rest of system
 - b) Tube winding mandrel
- 3) Test structural integrity - conduct same structural tests used on 5C boiler
- 4) Test thermal performance
 - a) Steady state operation
 - b) Transient start capabilities
 - c) Conditioning

Obviously this program will require additional funding. This funding should be in addition to all current boiler funding as I believe both the 5C and 7 boilers worthy of the funds being expended upon them.

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TABLE II

CONCEPT CONSIDERATIONS	PROPOSAL 1 SHELL AND INNER CAN OF CROLOY	PROPOSAL 2 ALL CROLOY
Stress	Redesign Necessary (Not Major)	Suggested Concept
Hydrogen Diffusion	Suggested Concept	Increase Hydrogen in R/C 2-3 times
Materials, Corrosion and Joining	Acceptable	Suggested Concept
Thermal Performance	Acceptable	Acceptable
Fabrication	No Problem	New Mandrel Needed ~ \$20,000
Program	No Funding 5C and 7 should continue in any case	

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