Contra $rpsI$-Continuous Functions in Ideal Topological Spaces

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Abstract

In this paper, we apply the notion of $rpsI$-open sets to present and study a new class of functions called contra $rpsI$-Continuous functions in ideal topological spaces. Relationships between this new class and other classes of functions are investigated and some characterisations of this new class of functions are studied.

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1 Introduction

In 1996, Dontchev [2], introduced a new class of functions called Contra - Continuous functions. He defined a function $f : X \to Y$ to be Contra continuous if the preimage of every open set of $Y$ is closed in $X$. A new weaker form of this class of functions called Contra - $rps$ -continuous functions, is introduced and investigated by Shyla Isac Mary and Thangavelu [10]. We also obtain some properties of such functions. The subject of ideals in topological spaces has been studied by Kuratowski [6] and Vaidyanathaswamy [12].
Noiri, Jafari[7] introduced and investigated Contra pre-I-Continuous functions. Also Vadivel and Chandrasekar, Saraswathi[11] introduced Contra $\alpha I$-Continuous functions. In this direction, we will introduce the concept of contra $rps I$-functions via the notion of $rsp I$-closed sets.

2 Preliminaries

Definition 2.1. [8] A subset $A$ of an ideal topological space $(X, \tau, I)$ is called regular pre-semi I closed (briefly $rps I$-closed) if $\text{spcl}(A) \subseteq U$ whenever $A \subseteq U$ and $U$ is $rg I$-open.

Definition 2.2. [8] A subset $A$ of an ideal topological space $(X, \tau, I)$ is called regular generalized $I$ closed (briefly $rg I$-closed) if $\text{cl}^*(A) \subseteq U$ whenever $A \subseteq U$ and $U$ is regular $I$-open. The complement of $rg I$-closed set is $rg I$-open.

Definition 2.3. A subset $A$ of an ideal topological space $(X, \tau, I)$ is called
(i) regular I-open [5] if $A = \text{int}(\text{cl}^*(A))$.
(ii) pre $I$-open [2] if $A \subseteq \text{int}(\text{cl}^*(A))$.
(iii) semi I-open [3] if $A \subseteq \text{cl}(\text{int}(A))$.
(iv) $\alpha I$-open [3] if $A \subseteq \text{int}(\text{cl}^*(\text{int}(A)))$.

Definition 2.4. [10] A function $f : (X, \tau) \rightarrow (Y, \sigma)$ is called Contra $rps I$-continuous if $f^{-1}(V)$ is $rps I$-closed in $(X, \tau, I)$ for each open set $V$ in $(Y, \sigma)$.

Definition 2.5. A function $f : (X, \tau, I) \rightarrow (Y, \sigma)$ is called
(i) Contra pre $I$-continuous [7] if $f^{-1}(V)$ is pre-$I$-open in $(X, \tau, I)$, for every closed set $V$ of $(Y, \sigma)$.
(ii) Contra $\alpha I$-continuous [11] if $f^{-1}(V)$ is $\alpha I$-open in $(X, \tau, I)$ for every closed set $V$ of $(Y, \sigma)$.
(iii) Contra semi $I$-continuous [4] if $f^{-1}(V)$ is semi-$I$-open in $(X, \tau, I)$ for every closed set $V$ of $(Y, \sigma)$.
(iv) Contra continuous [1] if $f^{-1}(V)$ is closed in $(X, \tau)$ for every open set $V$ in $(Y, \sigma)$.
(v) $rps I$-continuous [9] if $f^{-1}(V)$ is $rps I$-open in $(X, \tau)$ for every open set $V$ in $(Y, \sigma)$. 
Lemma 2.6. [8]
(i) Every semi-I-closed set is rpsI-closed
(ii) Every pre-I-closed set is rpsI-closed
(iii) Every $\alpha I$-closed set is rpsI-closed.
(iv) Every closed set is rpsI-closed.

Definition 2.7. A function $f : (X, \tau, I) \to (Y, \sigma)$ is called rpsI-irresolute [9] if $f^{-1}(A)$ is rpsI-closed in $X$, for every rpsI-closed subset $A$ of $Y$.

Definition 2.8. A space $X$ is locally indiscrete [10] if every open subset of $X$ is closed.

3 Contra rpsI-Continuous Functions

In this section, we introduce contra rpsI-continuous functions.

Definition 3.1. A function $f : (X, \tau, I) \to (Y, \sigma)$ is called contra rpsI-continuous if $f^{-1}(V)$ is rpsI-closed in $(X, \tau, I)$ for each open set $V$ in $(Y, \sigma)$.

Theorem 3.2. Every contra semi I-continuous function is contra rpsI-continuous.

Proof. Suppose $f : (X, \tau, I) \to (Y, \sigma)$ is contra semi-I-continuous function. Let $V$ be an open set in $Y$. Since $f$ is contra semi-I-continuous, we have $f^{-1}(V)$ is semi-I-closed in $X$. Again using lemma 2.6, $f^{-1}(V)$ is rpsI-closed in $X$. Therefore by using definition 3.1, $f$ is contra rpsI-continuous.

The converse of the above theorem need not be true as seen from the following example.

Example 3.3. Consider $X = Y = \{a, b, c, d\}$, $\tau = \{\phi, Y, \{a\}, \{b, d\}, \{a, b, d\}\}$, $\sigma = \{\phi, X, \{a\}, \{b\}, \{a, b\}, \{b, c\}, \{a, b, c\}\}$, $I = \{\phi, \{a\}\}$ and $f(a) = a$, $f(b) = b$, $f(c) = c$, $f(d) = a$. Then $f$ is contra rpsI-continuous but not contra semi I-continuous because the set $f^{-1}(b) = \{b\}$ which is rpsI-closed but not semi-I closed in $X$.

Theorem 3.4. Every contra $\alpha I$-continuous function is contra rpsI-continuous.

Proof. Suppose $f : (X, \tau, I) \to (Y, \sigma)$ is contra $\alpha - I$-continuous function. Let $V$ be an open set in $Y$. Then $V^c$ is closed in $Y$. Since $f$ is contra $\alpha - I$ continuous function, using Definition 2.5, $f^{-1}(V^c)$ is $\alpha I$-open in $X$. But $f^{-1}(V^c) = [f^{-1}(V)]^c$ which is $\alpha I$ open in $X$. Therefore $f^{-1}(V)$ is $\alpha I$-closed in $X$. Again using Lemma 2.6, $f^{-1}(V)$ is rpsI-closed in $X$. Then by using Definition 3.1, $f$ is contra rpsI-continuous.
The converse of the above theorem need not be true as seen from the following example.

**Example 3.5.** Consider \( X = Y = \{a, b, c, d\}, \tau = \{\phi, X, \{a\}, \{b\}, \{a, b\}, \{b, c\}, \{a, b, c\}\}, \sigma = \{\phi, Y, \{a\}, \{b\}, \{a, b\}, \{b, c\}, \{a, b, c\}\}, \mathcal{I} = \{\phi, \{a\}\} \) and \( f(a) = a, f(b) = b, f(c) = c, f(d) = d. \) Then \( f \) is contra rpsI-continuous but not contra \( \alpha - I \) continuous because the set \( f^{-1}(a) = \{a\} \) which is rpsI-closed but not \( \alpha I \)-closed.

**Theorem 3.6.** Every contra pre-I-continuous function is contra rpsI-continuous.

*Proof.* Suppose \( f : (X, \tau, \mathcal{I}) \to (Y, \sigma) \) is contra pre-I continuous function. Let \( V \) be an open set in \( Y. \) Then \( V^c \) is closed in \( Y. \) Since \( f \) is contra pre-I-continuous function, using Definition 2.5(i), \( f^{-1}(V^c) \) is pre-I-open in \( X. \) But \( f^{-1}(V^c) = [f^{-1}(V)]^c \) which is pre-I-open in \( X. \) Therefore \( f^{-1}(V) \) is pre-I-closed in \( X. \) Again using Lemma 2.6, \( f^{-1}(V) \) is rpsI-closed in \( X. \) Then by using Definition 3.1, \( f \) is contra rpsI-continuous.

But the converse of the above theorem need not be true as seen from the following example.

**Example 3.7.** Consider \( X = Y = \{a, b, c, d\}, \tau = \{\phi, X, \{a\}, \{b\}, \{a, b\}, \{a, b, c\}\}, \sigma = \{\phi, Y, \{a\}, \{b\}, \{a, b\}, \{b, c\}, \{a, b, c\}\}, \mathcal{I} = \{\phi, \{a\}\}, f(a) = d, f(b) = a, f(c) = c, f(d) = a. \) Then \( f \) is contra rpsI-continuous but not contra pre-I-continuous because the set \( f^{-1}(a) = \{b, d\} \) is rpsI-closed but not pre-I closed.

**Theorem 3.8.** Every contra continuous function is contra rpsI-continuous.

The proof follows from Lemma 2.6 and Definition 2.5.

The following example show that the concepts of rpsI-continuity and contra rpsI-continuity are independent of each other.

**Example 3.9.** Let \( X = Y = \{a, b, c, d\}, \tau = \{\phi, X, \{a\}, \{b\}, \{a, b\}, \{a, b, c\}, \{a, b, c\}\}, \sigma = \{\phi, Y, \{a\}, \{b\}, \{a, b\}, \{b, c\}, \{a, b, c\}\}, \mathcal{I} = \{\phi, \{a\}\} \) and \( \mathcal{I} = \{\phi, \{a\}\}. \) Let \( f : (X, \tau, \mathcal{I}) \to (Y, \sigma) \) be defined by \( f(a) = b, f(b) = a, f(c) = d \) and \( f(d) = c. \) Observe that \( f \) is rpsI-continuous. But \( f \) is not contra rpsI-continuous, since \( \{a\} \) is open and \( f^{-1}(\{a\}) = \{b\} \) is not rpsI-closed.

**Example 3.10.** Let \( X = Y = \{a, b, c, d\}, \tau = \{\phi, X, \{a\}, \{b\}, \{a, b\}, \{a, b, c\}, \{a, b, c\}\}, \sigma = \{\phi, Y, \{a\}, \{b\}, \{a, b\}, \{b, c\}, \{a, b, c\}\}, \mathcal{I} = \{\phi, \{a\}\} \) and \( \mathcal{I} = \{\phi, \{a\}\}. \) Let \( f : (X, \tau, \mathcal{I}) \to (Y, \sigma) \) be defined by \( f(a) = d, f(b) = c, f(c) = b \) and \( f(d) = a. \) Observe that \( f \) is contra rpsI-continuous. But \( f \) is not rpsI-continuous, since \( \{a\} \) is open and \( f^{-1}(\{a\}) = \{d\} \) is not rpsI-open.

**Definition 3.11.** An ideal space \((X, \tau, \mathcal{I})\) is called rpsI-locally indiscrete if every rpsI-open subset of \( X \) is closed.
Theorem 3.12. Let \( f : (X, \tau, \mathcal{I}) \to (Y, \sigma) \) be a function.

(i) If \( f \) is \( rpsI \)-continuous and if \( X \) is \( rpsI \)-locally indiscrete, then \( f \) is contra continuous.

(ii) If \( f \) is \( rpsI \)-continuous and if \( Y \) is locally indiscrete, then \( f \) is contra \( rpsI \)-continuous.

Proof. (i) Suppose \( f \) is \( rpsI \)-continuous. Let \( X \) be \( rpsI \)-locally indiscrete and \( V \) be open in \( Y \). Since \( f \) is \( rpsI \)-continuous by using Definition 2.5(v), \( f^{-1}(V) \) is \( rpsI \)-open in \( X \). Since \( X \) is \( rpsI \)-locally indiscrete using Definition 3.11, \( f^{-1}(V) \) is closed in \( X \). Therefore by using Definition 2.5(iv), \( f \) is contra continuous. This proves (i).

(ii) Suppose \( f \) is \( rpsI \)-continuous. Let \( Y \) be locally indiscrete and \( V \) be open subset of \( Y \). Since \( Y \) is locally indiscrete by using Definition 2.8, \( V \) is closed. Since \( f \) is \( rpsI \)-continuous by using Definition 2.5(v), \( f^{-1}(V) \) is \( rpsI \)-closed in \( X \). Therefore by using Definition 3.1, \( f \) is contra \( rpsI \)-continuous. This proves (ii). \( \square \)

Theorem 3.13. For a function \( f : (X, \tau, \mathcal{I}) \to (Y, \sigma) \) the following are equivalent.

(i) \( f \) is contra \( rpsI \)-continuous.

(ii) For every closed subset \( F \) of \( Y \), \( f^{-1}(F) \) is \( rpsI \)-open in \( X \).

Proof. (i) \( \implies \) (ii) Given \( f \) is contra \( rpsI \)-continuous. We have for every open set \( V \) in \( Y \), \( f^{-1}(V) \) is \( rpsI \)-closed in \( X \). Let \( F \) be a closed subset of \( Y \). Then \( F^c \) is open subset of \( Y \), \( f^{-1}(F^c) \) is \( rpsI \)-closed in \( X \). But \( f^{-1}(F^c) = (f^{-1}(F))^c \) which is \( rpsI \)-closed in \( X \). Thus \( f^{-1}(F) \) is \( rpsI \)-open in \( X \).

(ii) \( \implies \) (i) Let \( V \) be an open set in \( Y \). Then \( V^c \) is closed in \( Y \) which implies \( f^{-1}(V^c) \) is \( rpsI \)-open in \( X \). But \( f^{-1}(V^c) = (f^{-1}(V))^c \) which is \( rpsI \)-open in \( X \). Thus \( f^{-1}(V) \) is \( rpsI \)-closed in \( X \) and hence \( f \) is contra \( rpsI \)-continuous. \( \square \)

Theorem 3.14. Contra \( rpsI \)-continuous image of a \( rpsI \)-connected space is connected.

Proof. Let \( f \) be a contra \( rpsI \)-continuous function from a \( rpsI \)-connected space \( X \) onto a space \( Y \). Assume that \( Y \) is disconnected. Then \( Y = A \cup B \), where \( A \) and \( B \) are disjoint non-empty open sets in \( Y \) with \( A \cap B = \phi \). Since \( f \) is contra \( rpsI \)-continuous, we have \( f^{-1}(A) \) and \( f^{-1}(B) \) are \( rpsI \)-closed sets in \( X \) with \( f^{-1}(A) \cup f^{-1}(B) = f^{-1}(A \cup B) = f^{-1}(Y) = X \) and \( f^{-1}(A) \cap f^{-1}(B) = f^{-1}(A \cap B) = f^{-1}(\phi) = \phi \). This means that \( X \) is not \( rpsI \)-connected which is a contradiction. Then \( Y \) is connected. \( \square \)

From Theorem 3.22 and Theorem 3.10, we have the following diagram.
4 Contra \( rpsI \)-irresolute functions

In this section, we introduce contra \( rpsI \)-irresolute functions.

**Definition 4.1.** A function \( f : (X, \tau, I) \to (Y, \sigma) \) is called Contra \( rpsI \)-irresolute if \( f^{-1}(V) \) is \( rpsI \)-closed in \( X \), for every \( rpsI \)-open set \( V \) of \( Y \).

**Remark 4.2.** Contra \( rpsI \)-irresolute and \( rpsI \)-irresolute functions are independent of each other.

**Example 4.3.** Consider the ideal topological space \( (X, \tau, I) \), where \( X = Y = \{a, b, c, d\} \), \( \tau = \{\emptyset, X, \{a\}, \{b\}, \{a, b\}, \{a, c\}, \{b, c\}, \{a, b, c\}\} \) and \( \sigma = \{\emptyset, Y, \{a\}, \{b, d\}, \{a, b, d\}\} \). Let \( f : (X, \tau, I) \to (Y, \sigma) \) be defined by \( f(a) = d, f(b) = c, f(c) = b, f(d) = a \). Then \( f \) is Contra \( rpsI \)-irresolute but not \( rpsI \)-irresolute because the set \( \{c\} \) is \( rpsI \)-closed in \( Y \), but \( f^{-1}(c) = \{b\} \) is not \( rpsI \)-closed in \( X \).

**Example 4.4.** Consider the ideal topological space \( (X, \tau, I) \), where \( X = Y = \{a, b, c\} \), \( \tau = \{\emptyset, X, \{a\}, \{a, b\}\} \), \( I = \{\emptyset, \{b\}\} \), \( \sigma = \{\emptyset, Y, \{b\}, \{a, b\}\} \) and \( \mathcal{J} = \{\emptyset, \{a\}\} \). A function \( f : (X, \tau, I) \to (Y, \sigma, \mathcal{J}) \) defined by \( f(a) = b, f(b) = a, f(c) = c \). Then \( f \) is \( rpsI \)-irresolute but not contra \( rpsI \)-irresolute because the set \( \{b\} \) is \( rpsI \)-open in \( Y \) but \( f^{-1}(b) = \{a\} \) which is not \( rpsI \)-closed in \( X \).

**Theorem 4.5.** Let \( f : (X, \tau, I) \to (Y, \sigma) \) and \( g : (Y, \sigma, \mathcal{J}) \to (Z, \mu) \). Then

(i) \( g \circ f \) is Contra \( rpsI \)-irresolute if \( g \) is \( rpsI \)-irresolute and \( f \) is contra \( rpsI \)-irresolute.

(ii) \( g \circ f \) is contra \( rpsI \)-irresolute if \( g \) is contra \( rpsI \)-irresolute and \( f \) is \( rpsI \)-irresolute.

**Proof.** (i) Let \( V \) be a \( rpsI \)-open subset of \( Z \). Then \( V^c \) is \( rpsI \)-closed subset of \( Z \). Since \( g \) is \( rpsI \)-irresolute, we have \( g^{-1}(V^c) \) is \( rpsI \)-closed set in \( Y \). Also,
A function \( f : (X, \tau, I) \to (Y, \sigma) \) is said to be rpsI-homeomorphism iff (i) \( f \) is bijective (ii) \( f \) is rpsI-continuous (iii) \( f^{-1} \) is rpsI-continuous.

Theorem 4.7. Let \((X, \tau, I)\) and \((Y, \sigma, J)\) be an ideal topological spaces and let \( f \) be a bijective mapping of \( X \) onto \( Y \). Then the following statements are equivalent.

(a) \( f \) is a rpsI-homeomorphism

(b) \( f \) is rpsI-continuous and rpsI-open

(c) \( f \) is rpsI-continuous and rpsI-closed.

Proof. (a) \( \implies \) (b) Assume (a). Let \( g \) be the inverse mapping of \( f \) so that \( f^{-1} = g \) and \( g^{-1} = f \). Since \( f \) is bijection, \( g \) is also bijection. Let \( G \) be a open set in \( X \). Since \( f \) is a homeomorphism, \( g^{-1}(G) \) is rpsI-open in \( Y \). But \( g^{-1} = f \) so that \( g^{-1}(G) = f(G) \) which is rpsI-open in \( Y \). It follows that \( f \) is a rpsI open mapping. Clearly \( f \) is rpsI-continuous. Hence (a) \( \implies \) (b).

(b) \( \implies \) (a) Assume \( f \) is a bijection and rpsI-continuous, rpsI-open. Enough to prove that \( f^{-1} \) is rpsI-continuous. Let \( G \) be open in \( X \). Then by hypothesis, \( f(G) \) is rpsI-open in \( Y \). Therefore \( g^{-1}(G) \) is rpsI-open in \( Y \) and so \( g = f^{-1} \) is rpsI-continuous. Hence (b) \( \implies \) (a).

(a) \( \implies \) (c) Assume (a). Let \( H \) be closed set in \( X \). Then \( H^c \) is open in \( X \). Since \( g = f^{-1} \) is rpsI-continuous, it follows that \( g^{-1}(H^c) \) is rpsI-open in \( Y \). But \( g^{-1}(H^c) = g^{-1}(X - H) = g^{-1}(X) - g^{-1}(H) = Y - g^{-1}(H) \). Hence \( Y - g^{-1}(H) \) is rpsI-open in \( Y \). That is, \( g^{-1}(H) \) is rpsI-closed in \( Y \) which implies \( f(H) \) is rpsI-closed in \( Y \). Hence \( f \) is rpsI-closed map. This proves (a) \( \implies \) (c).

(c) \( \implies \) (a) Assume (c). Let \( G \) be any open set in \( X \). Then \( G^c \) is closed in \( X \). Since \( f \) is a rpsI-closed map, \( f(G^c) = g^{-1}(X - G) = g^{-1}(X) - g^{-1}(G) = Y - g^{-1}(G) \) is rpsI-closed in \( Y \). That is, \( g^{-1}(G) \) is rpsI-open in \( Y \). Thus inverse image of every open set in \( X \) is rpsI-open in \( Y \). Hence \( g = f^{-1} \) is rpsI-continuous and so \( f \) is a homeomorphism.

Theorem 4.8. Let \((X, \tau, I)\), \((Y, \sigma, J)\) and \((Z, \rho, K)\) be three ideal topological spaces. If \( f : (X, \tau, I) \to (Y, \sigma, J) \) and \( g : (Y, \sigma, J) \to (Z, \rho, K) \) are rpsI-homeomorphisms, then \( g \circ f : (X, \tau, I) \to (Z, \rho, K) \) is also a rpsI-homeomorphism.
Proof. (i) \( f \) is 1-1, onto and \( g \) is 1-1, onto which implies \( g \circ f \) is 1-1, onto.
(ii) \( f \) is \( rpsI \)-continuous and \( g \) is \( rpsI \)-continuous which implies \( g \circ f \) is \( rpsI \)-continuous.
(iii) \( g^{-1} \) is \( rpsI \)-continuous and \( f^{-1} \) is \( rpsI \)-continuous implies \( f^{-1} \circ g^{-1} \) is \( rpsI \)-continuous and so \((g \circ f)^{-1}\) is \( rpsI \)-continuous.
From (i), (ii) and (iii), \( g \circ f \) is a \( rpsI \)-homeomorphism. 

Definition 4.9. A function \( f : (X, \tau, I) \rightarrow (Y, \sigma) \) is called totally \( rpsI \)-continuous if \( f^{-1}(V) \) is \( rpsI \)-clopen in \( X \), for every open set \( V \) in \( Y \).

Theorem 4.10. (i) Every totally \( rpsI \)-continuous function is \( rpsI \)-continuous.
(ii) Every totally \( rpsI \)-continuous function is contra \( rpsI \)-continuous.

The converse of the above statements need not be true as seen from the following example.

Example 4.11. Consider the ideal topological space in example 4.4. Define a function \( f : (X, \tau, I) \rightarrow (Y, \sigma, J) \) by \( f(a) = b, f(b) = a, f(c) = c \). Then \( f \) is \( rpsI \)-continuous but not totally \( rpsI \)-continuous because the set \( \{b\} \) is open in \( Y \) but \( f^{-1}(b) = \{a\} \) which is \( rpsI \)-open and not \( rpsI \)-closed in \( X \).

Example 4.12. Consider the ideal topological space in example 4.4. Define a function \( f : (X, \tau, I) \rightarrow (Y, \sigma, J) \) by \( f(a) = a, f(b) = c, f(c) = b \). Then \( f \) is contra \( rpsI \)-continuous but not totally \( rpsI \)-continuous because the set \( \{b\} \) is open in \( Y \) \( f^{-1}(b) = \{c\} \) which is \( rpsI \)-closed and not \( rpsI \)-open in \( X \).

Remark 4.13. \( rpsI \)-continuous and contra \( rpsI \)-continuous functions are independent of each other. This can be observed from the following example.

Example 4.14. Consider the ideal topological space in example 4.4. Define a function \( f : (X, \tau, I) \rightarrow (Y, \sigma, J) \) by \( f(a) = b, f(b) = c, f(c) = a \). Then \( f \) is \( rpsI \)-continuous but not contra \( rpsI \)-continuous because the set \( \{b\} \) is open in \( Y \) but \( f^{-1}(b) = \{a\} \) which is \( rpsI \)-open and not \( rpsI \)-closed in \( X \).

Example 4.15. Consider the ideal topological space in example 4.4. Define a function \( f : (X, \tau, I) \rightarrow (Y, \sigma, J) \) by \( f(a) = a, f(b) = b, f(c) = c \). Then \( f \) is contra \( rpsI \)-continuous but not \( rpsI \)-continuous because the set \( \{b\} \) is open in \( Y \) but \( f^{-1}(b) = \{b\} \) which is \( rpsI \)-closed and not \( rpsI \)-open in \( X \).

From theorem 4.10 to remark 4.13, we have the following diagram.

\[
\begin{array}{c}
\text{Totally} \ rpsI \text{-continuous} \\
\downarrow \ \ \downarrow \\
\text{rpsI-continuous} \ \\ \\
\leftarrow \rightleftharpoons \\
\text{Contra} \ rpsI \text{-continuous}
\end{array}
\]
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References


