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Integral Transform Involving the Product of a General Class of Polynomals, Struve's Function, H-Function of One and r Variables

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Abstract

The object of this paper is to establish integrals involving the product of general class of polynomials, Struve's function, H-function of one and r variables. Some special cases have also derived.

Keywords: Mellin transform, Struve's function, H-function

1 Introduction and Preliminaries

Recently, The Mellin transform of the product of general class of polynomials, H-function of one and r variables [2] are evaluated. In the present paper we establish the integral transform of product of general class of polynomials, Struve's function, H-function of one and r variales.

We shall utilized the following formulae in the present investigation. The H-function of r variables given by H.M.Srivastava and R. Panda [6]

(1.1) $H[x_1, x_2, ..., x_r] =$

$$H^{0,n:m_1,n_1;....;m_r,n_r}_{p,q:p_1,q_1;....;p_r,q_r}\left[\begin{array}{c|c} x_1 & (a_j;\alpha_{1j},....,\alpha_{rj})_{1,p} : (c_{1j},C_{1j})_{1,p_1};....;(c_{rj},C_{rj})_{1,p_r} \\ . & \\ . & \\ . & \\ x_r & (b_j;\beta_{1j},....,\beta_{rj})_{1,q} : (d_{1j},D_{1j})_{1,q_1};....;(d_{rj},D_{rj})_{1,q_r} \end{array}\right]$$

$$= \frac{1}{(2\pi i)^r}\int_{L_1}....\int_{L_r}\theta(s_1,...,s_r)\prod_{k=1}^{r}\phi_k(s_k)x_k^{s_k}ds_k, i=\sqrt{-1}$$

Where

$$\theta(s_1,....,s_r) = \frac{\prod_{j=1}^{n}\Gamma(1-a_j+\sum_{k=1}^{r}\alpha_j^{(k)}s_k)}{\prod_{j=n+1}^{p}\Gamma(a_j-\sum_{k=1}^{r}\alpha_j^{(k)}s_k)\prod_{j=1}^{q}\Gamma(1-b_j+\sum_{k=1}^{r}\beta_j^{(k)}s_k)}$$

$$\phi_k(s_k) = \frac{\prod_{j=1}^{m_k}\Gamma(d_j^{(k)}-D_j^{(k)}s_k)\prod_{j=1}^{n_k}\Gamma(1-c_j^{(k)}+C_j^{(k)}s_k)}{\prod_{j=m_k+1}^{q_k}\Gamma(1-d_j^{(k)}+D_j^{(k)}s_k)\prod_{j=n_k+1}^{p_k}\Gamma(c_j^{(k)}-C_j^{(k)}s_k)}, k=1,...,r$$

where n, p, q, m_k,n_k, p_k, q_k, $k = 1, 2, ..., r$ are non-negative integers such that $0 \leq n \leq p$, $q \geq 0$, $0 \leq m_k \leq q_k$ and $0 \leq n_k \leq p_k$, $k = 1, 2, ..., r$. $\alpha_j^{(k)}$, $\beta_j^{(k)}$, $C_j^{(k)}$, $D_j^{(k)}$ are all positive.

The contour L_k lies in the complex plane s_k is of Mellin-Barnes type which runs from $-i\infty$ to $+i\infty$ with intendations, if necessary to ensure that all poles of $\Gamma(d_j^{(k)} - D_j^{(k)}s_k)$, $j = 1, 2, ..., n_k$ and $\Gamma(1 - a_j^{(k)} + \sum\alpha_j^{(k)}s_k)$,$j = 1, 2, ..., n$ are to the left of L_k.

The H-function of one variable is defined as follows [4]

(1.2) $H^{m,n}_{p,q}\left[x| \begin{array}{c}(a_j,\alpha_j)_{1,p}\\(b_j,\beta_j)_{1,q}\end{array}\right] = \frac{1}{2\pi i}\int_L\theta(s)x^s ds$

where

$$\theta(s) = \frac{\prod_{j=1}^{m}\Gamma(b_j-\beta_j s)\prod_{j=1}^{n}\Gamma(1-a_j+\alpha_j s)}{\prod_{j=m+1}^{q}\Gamma(1-b_j+\beta_j s)\prod_{j=n+1}^{p}\Gamma(a_j-\alpha_j s)}$$

with all conditions detailed in [4]. Mellin transform of the H-function is defined as follows [4],

(1.3) $\int_0^\infty z^{s-1}H^{M,N}_{P,Q}\left[az| \begin{array}{c}(c_j,\gamma_j)_{1,P}\\(d_j,\delta_j)_{1,Q}\end{array}\right]dz = a^{-s}\theta(-s)$

where

$$\theta(-s)=\frac{\prod_{j=1}^{N}\Gamma((1-c_j)-\gamma_j s)\prod_{j=1}^{M}\Gamma(1-(1-d_j)+\delta_j s)}{\prod_{j=N+1}^{P}\Gamma(1-(1-c_j)+\gamma_j s)\prod_{j=M+1}^{Q}\Gamma((1-d_j)-\delta_j s)}$$

Provided the corresponding conditions stated in [4]. According to Prasanna Kumari [8, p.101]
(1.4)

$$\int_0^\infty x^{s-1}H_{p,q}^{m,n}\left[zx^\sigma\Big|\begin{array}{l}(a_j,A_j)_{1,p}\\(b_j,B_j)_{1,q}\end{array}\right]dx=\frac{\prod_{j=1}^{m}\Gamma(b_j-\beta_j\frac{s}{\sigma})\prod_{j=1}^{n}\Gamma(1-a_j-A_j\frac{s}{\sigma})}{\sigma z^{\frac{s}{\sigma}}\prod_{j=m+1}^{q}\Gamma(1-b_j-B_j\frac{s}{\sigma})\prod_{j=n+1}^{p}\Gamma(a_j+A_j\frac{s}{\sigma})}$$

The class of polynomials [10]
(1.5)

$$S_n^m[x]=\sum_{k=0}^{[n/m]}\frac{(-n)_{mk}}{k!}A_{n,k}x^k, n=0,1,2,3,....$$

where m is an arbitrary positive integer and the co-efficients $A_{n,k}(n,k\geq 0)$ are arbitrary constants.

The Struve's function is defined as [13] (and also see [12])
(1.6)

$$H_{v,y,u}^{\lambda,k}[z]=\sum_{m=0}^{\infty}\frac{(-1)^m(z/2)^{v+2m+1}}{\Gamma(km+y)\Gamma(v+\lambda m+u)}$$

$Re(k)>0$, $Re(\lambda)>0$, $Re(y)>0$, $Re(v+u)>0$.

2.Main Result:

$$(2.1)\ \int_0^\infty x^{s-1}S_n^m[ax^h]H_{v,y,u}^{\lambda,\ell}[bx^\delta]H_{p,q}^{m,n}\left[\eta x^\rho\Big|\begin{array}{l}(e_j,E_j)_{1,p}\\(f_j,F_j)_{1,q}\end{array}\right]\times$$

$$H_{P,Q:p_1,q_1;...;p_r,q_r}^{0,N:m_1,n_1;...;m_r,n_r}\left[\begin{array}{c}t_1x^{\sigma_1}\\ \cdot\\ \cdot\\ \cdot\\ t_rx^{\sigma_r}\end{array}\middle|\begin{array}{l}(a_j;\alpha_{1j},...,\alpha_{rj})_{1,P}:(c_{1j},C_{1j})_{1p_1};...;(c_{rj},C_{rj})_{1p_r}\\ \\ \\(b_j;\beta_{1j},...,\beta_{rj})_{1,Q}:(d_{1j},D_{1j})_{1q_1};...;(d_{rj},D_{rj})_{1q_r}\end{array}\right]dx$$

$$=\frac{1}{\rho}\sum_{k=0}^{[n/m]}\frac{(-n)_{mk}}{k!}A_{n,k}a^k\sum_{u=0}^{\infty}f(u)\eta^{\frac{-g(u,k)}{\rho}}\times$$

$$H^{n,N+m:m_1,n_1;\dots;m_r,n_r}_{P+q,Q+p:p_1,q_1;\dots;p_r,q_r}\left[\begin{array}{c|l} \frac{t_1}{\eta^{\frac{\sigma_1}{\rho}}} & (a_j;\alpha_{1j},...,\alpha_{rj})_{1,N},(1-f_j-F_j(\frac{g(u,k)}{\rho}); \\ \cdot & \\ \cdot & \\ \cdot & \\ \frac{t_r}{\eta^{\frac{\sigma_r}{\rho}}} & (1-e_j-E_j(\frac{g(u,k)}{\rho});E_j\frac{\sigma_1}{\rho},...,E_j\frac{\sigma_r}{\rho})_{1,p}, \end{array}\right.$$

$$\left.\begin{array}{l} F_j\frac{\sigma_1}{\rho},...,F_j\frac{\sigma_r}{\rho})_{1,q},(a_j;\alpha_{1j},...,\alpha_{rj})_{N+1,P}:(c_{1j},C_{1j})_{1,p_1};...;(c_{rj},C_{rj})_{1,p_r} \\ (b_j;\beta_{1j},...,\beta_{rj})_{1,Q}:(d_{1j},d_{1j})_{1,p_1};...;(d_{rj},D_{rj})_{1,q_r} \end{array}\right]$$

where

$$f(u)=\frac{(-1)^u(b/2)^{v+2u+1}}{\Gamma(\ell u+y)\Gamma(v+\lambda u+\mu)};g(u,k)=s+hk+\delta(v+2u+1)$$

Provided

(i) $\sigma_i>0$, for i=1,2,...,r, $\sigma>0$, $\delta>0$, $h>0$

(ii) $A_i\le 0$; $U_i>0$, $\theta>0$

$A_i+\frac{1}{\rho}\left[\sum_{j=1}^{q}F_j\sigma_i-\sum_{j=1}^{p}F_j\sigma_i\right]\le 0,$

$U_i-\frac{1}{\rho}\left[\sum_{j=m+1}^{q}F_j\sigma_i+\sum_{j=1}^{p}F_j\sigma_i\right]>0,$

where

$\theta=\sum_{j=1}^{n}E_j-\sum_{j=n+1}^{p}E_j+\sum_{j=1}^{m}F_j-\sum_{j=m+1}^{q}F_j$,

$A_i=\sum_{j=1}^{P}\alpha_j^{(i)}+\sum_{j=n+1}^{p_1}C_j^{(i)}-\sum_{j=1}^{Q}\beta_j^{(i)}-\sum_{j=m+1}^{q_1}D_j^{(i)}$,

$U_i=-\sum_{j=N+1}^{P}\alpha_j^{(i)}-\sum_{j=1}^{Q}\beta_j^{(i)}+\sum_{j=1}^{ni}C_j^{(i)}-\sum_{j=ni+1}^{pi}C_j^{(i)}+\sum_{j=1}^{mi}D_j^{(i)}-\sum_{j=mi+1}^{qi}D_j^{(i)},$

$i=1,...,r.$

Proof of main result:

Express the H-function of r-variables involved in the left hand side of (2.1) as a contour integral using (1.1) and the general class of polynomials, generalized Struve's function [3] as infinite series. Change the order of integration and summation and evaluate the inner integral using (1.4), the left hand side of (2.1) becomes,

$$\frac{1}{\rho}\sum_{k=0}^{[n/m]}\frac{(-n)_{mk}}{k!}A_{n,k}a^k\sum_{u=0}^{\infty}f(u)\eta^{-\frac{g(u,k)}{\rho}}\frac{1}{(2\pi i)^r}\int_{L_1}...\int_{L_r}\theta(s_1,...,s_r)\phi(s_1)...\phi(s_r)$$

$$\frac{\prod_{j=1}^{m}\Gamma\left(f_j+\frac{F_j(g(u,k)+\sigma_1s_1+...+\sigma_rs_r)}{\rho}\right)\prod_{j=1}^{n}\Gamma\left(1-e_j-\frac{E_j(g(u,k)+\sigma_1s_1+...+\sigma_rs_r)}{\rho}\right)}{\prod_{j=m+1}^{q}\Gamma\left(1-f_j-\frac{F_j(g(u,k)+\sigma_1s_1+...+\sigma_rs_r)}{\rho}\right)\prod_{j=n+1}^{p}\Gamma\left(e_j+\frac{E_j(g(u,k)+\sigma_1s_1+...+\sigma_rs_r)}{\rho}\right)}$$

$$\times\left(\frac{t_1}{\eta^{\frac{\sigma_1}{\rho}}}\right)^{s_1}...\left(\frac{t_r}{\eta^{\frac{\sigma_r}{\rho}}}\right)^{s_r}\ ds_1...ds_r$$

where $\phi_i(s_i)$ for i=1,2,...r, $\theta(s_1,s_2,...,s_r)$ are given by (1.1),from which right hand side of (2.1) is obtained by using (1.1). The change of order of integration is justified, when the given conditions are satisfied because of the absolute convergence of the integral involved.

3. Special cases:

Put h=0, a=1 in (2.1) we get Mellin transform of product of Struve's function, H-function of one variable and H-function of r-variables.

$$(3.1)\ \int_0^\infty x^{s-1}H^{\lambda,\ell}_{v,y,u}[bx^\delta]H^{m,n}_{p,q}\left[\eta x^\rho|\ \begin{matrix}(e_j,E_j)_{1,p}\\(f_j,F_j)_{1,q}\end{matrix}\right]\times$$

$$H^{0,N:m_1,n_1;...;m_r,n_r}_{P,Q:p_1,q_1;...;p_r,q_r}\left[\begin{matrix}t_1x^{\sigma_1}\\ \cdot\\ \cdot\\ \cdot\\ t_rx^{\sigma_r}\end{matrix}\left|\begin{matrix}(a_j;\alpha_{1j},...,\alpha_{rj})_{1,P}:(c_{1j},C_{1j})_{1p_1};...;(c_{rj},C_{rj})_{1p_r}\\ \\ \\(b_j;\beta_{1j},...,\beta_{rj})_{1,Q}:(d_{1j},D_{1j})_{1q_1};...;(d_{rj},D_{rj})_{1q_r}\end{matrix}\right.\right]dx$$

$$=\frac{1}{\rho}\sum_{u=0}^{\infty}f(u)\eta^{-g(u)}\times$$

$$H^{n,N+m:m_1,n_1;....;m_r,n_r}_{P+q,Q+p:p_1,q_1;....;p_r,q_r}\left[\begin{matrix}\frac{t_1}{\eta^{\frac{\sigma_1}{\rho}}}\\ \cdot\\ \cdot\\ \cdot\\ \frac{t_r}{\eta^{\frac{\sigma_r}{\rho}}}\end{matrix}\left|\begin{matrix}(a_j;\alpha_{1j},...,\alpha_{rj})_{1,N},(1-f_j-F_j(g(u));\\ \\ \\(1-e_j-E_j(g(u));E_j\frac{\sigma_1}{\rho},...,E_j\frac{\sigma_r}{\rho})_{1,p},\end{matrix}\right.\right.$$

$$\left.\begin{matrix}F_j\frac{\sigma_1}{\rho},...,F_j\frac{\sigma_r}{\rho})_{1,q},(a_j;\alpha_{1j},...,\alpha_{rj})_{N+1,P}:(c_{1j},C_{1j})_{1,p_1};...;(c_{rj},C_{rj})_{1,p_r}\\(b_j;\beta_{1j},...,\beta_{rj})_{1,Q}:(d_{1j},d_{1j})_{1,p_1};...;(d_{rj},D_{rj})_{1,q_r}\end{matrix}\right]$$

where

$$f(u)=\frac{(-1)^u(b/2)^{v+2u+1}}{\Gamma(\ell u+y)\Gamma(v+\lambda u+\mu)};g(u)=\frac{s+\delta(v+2u+1)}{\rho}$$

Put $\delta=0$, b=1 in (2.1) we get Mellin transform of product of general class of polynomials, H-function of one variable and H-function of r-variables.

$$(3.2)\ \int_0^\infty x^{s-1}S^m_n[ax^h]H^{m,n}_{p,q}\left[\eta x^\rho|\ \begin{matrix}(e_j,E_j)_{1,p}\\(f_j,F_j)_{1,q}\end{matrix}\right]\times$$

$$H^{0,N:m_1,n_1;...;m_r,n_r}_{P,Q:p_1,q_1;...;p_r,q_r}\left[\begin{array}{c|c} t_1x^{\sigma_1} & (a_j;\alpha_{1j},...,\alpha_{rj})_{1,P}:(c_{1j},C_{1j})_{1p_1};...;(c_{rj},C_{rj})_{1p_r} \\ \vdots & \\ t_rx^{\sigma_r} & (b_j;\beta_{1j},...,\beta_{rj})_{1,Q}:(d_{1j},D_{1j})_{1q_1};...;(d_{rj},D_{rj})_{1q_r}\end{array}\right]dx$$

$$=\frac{1}{\rho}\sum_{k=0}^{[n/m]}\frac{(-n)_{mk}}{k!}A_{n,k}a^k\eta^{\frac{-(s+hk)}{\rho}}\times$$

$$H^{n,N+m:m_1,n_1;....;m_r,n_r}_{P+q,Q+p:p_1,q_1;....;p_r,q_r}\left[\begin{array}{c|c} \frac{t_1}{\eta^{\frac{\sigma_1}{\rho}}} & (a_j;\alpha_{1j},...,\alpha_{rj})_{1,N},(1-f_j-F_j(s+hk); \\ \vdots & \\ \frac{t_r}{\eta^{\frac{\sigma_r}{\rho}}} & (1-e_j-E_j(s+hk);E_j\frac{\sigma_1}{\rho},...,E_j\frac{\sigma_r}{\rho})_{1,p},\end{array}\right.$$

$$\left.\begin{array}{l} F_j\frac{\sigma_1}{\rho},...,F_j\frac{\sigma_r}{\rho})_{1,q},(a_j;\alpha_{1j},...,\alpha_{rj})_{N+1,P}:(c_{1j},C_{1j})_{1,p_1};...;(c_{rj},C_{rj})_{1,p_r} \\ (b_j;\beta_{1j},...,\beta_{rj})_{1,Q}:(d_{1j},D_{1j})_{1,q_1};...;(d_{rj},D_{rj})_{1,q_r}\end{array}\right]$$

in (2.1) put N=0, to get

(3.3) $$\int_0^\infty x^{s-1}S_n^m[ax^h]H^{\lambda,\ell}_{v,y,u}[bx^\delta]H^{m,n}_{p,q}\left[\eta x^\rho\middle|\begin{array}{c}(e_j,E_j)_{1,p}\\(f_j,F_j)_{1,q}\end{array}\right]\times$$

$$H^{0,0:m_1,n_1;...;m_r,n_r}_{P,Q:p_1,q_1;...;p_r,q_r}\left[\begin{array}{c|c} t_1x^{\sigma_1} & (a_j;\alpha_{1j},...,\alpha_{rj})_{1,P}:(c_{1j},C_{1j})_{1p_1};...;(c_{rj},C_{rj})_{1p_r} \\ \vdots & \\ t_rx^{\sigma_r} & (b_j;\beta_{1j},...,\beta_{rj})_{1,Q}:(d_{1j},D_{1j})_{1q_1};...;(d_{rj},D_{rj})_{1q_r}\end{array}\right]dx$$

$$=\frac{1}{\rho}\sum_{k=0}^{[n/m]}\frac{(-n)_{mk}}{k!}A_{n,k}a^k\sum_{u=0}^{\infty}f(u)\eta^{\frac{-g(u,k)}{\rho}}\times$$

$$H^{n,m:m_1,n_1;...;m_r,n_r}_{P+q,Q+p:p_1,q_1;...;p_r,q_r}\left[\begin{array}{c|c} \frac{t_1}{\eta^{\frac{\sigma_1}{\rho}}} & (a_j;\alpha_{1j},...,\alpha_{rj})_{1,P},(1-f_j-F_j(\frac{g(u,k)}{\rho}); \\ \vdots & \\ \frac{t_r}{\eta^{\frac{\sigma_r}{\rho}}} & (1-e_j-E_j(\frac{g(u,k)}{\rho});E_j\frac{\sigma_1}{\rho},...,E_j\frac{\sigma_r}{\rho})_{1,p},\end{array}\right.$$

$$\left.\begin{array}{l} F_j\frac{\sigma_1}{\rho},...,F_j\frac{\sigma_r}{\rho})_{1,q},:(c_{1j},C_{1j})_{1,p_1};...;(c_{rj},C_{rj})_{1,p_r} \\ (b_j;\beta_{1j},...,\beta_{rj})_{1,Q}:(d_{1j},D_{1j})_{1,q_1};...;(d_{rj},D_{rj})_{1,q_r}\end{array}\right]$$

put P=Q=0 in (3.3)we get

$$(3.4)\ \int_0^\infty x^{s-1} S_n^m[ax^h] H_{v,y,u}^{\lambda,l}[bx^\delta]\, H_{p,q}^{m,n}\left[\eta x^\rho \left|{}^{(e_j,E_j)_{1,p}}_{(f_j,F_j)_{1,q}}\right.\right] \prod_{i=1}^{r} H_{p_i,q_i}^{m_i,n_i}\left[t_i x^{\sigma_i}\left|{}^{(c_j^{(i)},C_j^{(i)})_{1,p_i}}_{(d_j^{(i)},D_j^{(i)})_{1,q_i}}\right.\right] dx$$

$$= \frac{1}{\rho}\sum_{k=0}^{[n/m]} \frac{(-n)_{mk}}{k!} A_{n,k} a^k \sum_{u=0}^{\infty} f(u) \eta^{-\frac{g(u,k)}{\rho}} H_{q,p:p_1,q_1;\ldots;p_r,q_r}^{n,m:m_1,n_1;\ldots;m_r,n_r}\left[\begin{matrix}\frac{t_1}{\eta^{\frac{\sigma_1}{\rho}}}\\ \cdot\\ \cdot\\ \cdot\\ \frac{t_1}{\eta^{\frac{\sigma_1}{\rho}}}\end{matrix}\left|\begin{matrix}(1-f_j-(\frac{g(u,k)}{\rho}); F_j\frac{\sigma_1}{\rho},\ldots,F_j\frac{\sigma_r}{\rho})_{1,q}:(c_{1j})_{1,p_1};\ldots;(c_{rj})_{1,p_r}\\ (1-e_j-E_j(\frac{g(u,k)}{\rho}); E_j\frac{\sigma_1}{\rho},\ldots,E_j\frac{\sigma_r}{\rho})_{1,p},:(d_{1j},D_{1j})_{1,q_1};\ldots;(d_{rj},D_{rj})_{1,q_r}\end{matrix}\right.\right]$$

In (2.1) put $\alpha_j^{(i)} = \beta_j^{(i)} = C_j^{(i)} = D_j^{(i)} = E_j = F_j = 1$,
we get

$$(3.5)\ \int_0^\infty x^{s-1} S_n^m[ax^h] H_{v,y,u}^{\lambda,l}[bx^\delta]\, G_{p,q}^{m,n}\left[\eta x^\rho \left|{}^{(e_j)_{1,p}}_{(f_j)_{1,q}}\right.\right] \times$$

$$G_{P,Q:p_1,q_1;\ldots;p_r,q_r}^{0,N:m_1,n_1;\ldots;m_r,n_r}\left[\begin{matrix}t_1 x^{\sigma_1}\\ \cdot\\ \cdot\\ \cdot\\ t_r x^{\sigma_r}\end{matrix}\left|\begin{matrix}(a_j)_{1,P}:(c_{1j})_{1,p_1};\ldots;(c_{rj})_{1,p_r}\\ (b_j)_{1,Q}:(d_{1j})_{1,q_1};\ldots;(d_{rj})_{1,q_r}\end{matrix}\right.\right] dx$$

$$= \frac{1}{\rho}\sum_{k=0}^{[n/m]} \frac{(-n)_{mk}}{k!} A_{n,k} a^k \sum_{u=0}^{\infty} f(u) \eta^{-\frac{g(u,k)}{\rho}} \times$$

$$G_{P+q,Q+p:p_1,q_1;\ldots;p_r,q_r}^{n,N+m:m_1,n_1;\ldots;m_r,n_r}\left[\begin{matrix}\frac{t_1}{\eta^{\frac{\sigma_1}{\rho}}}\\ \cdot\\ \cdot\\ \cdot\\ \frac{t_1}{\eta^{\frac{\sigma_1}{\rho}}}\end{matrix}\left|\begin{matrix}(a_j)_{1,N},(1-f_j-(\frac{g(u,k)}{\rho}); \frac{\sigma_1}{\rho},\ldots,\frac{\sigma_r}{\rho})_{1,q},(a_j)_{N+1,P}:(c_{1j})_{1,p_1};\ldots;(c_{rj})_{1,p_r}\\ (1-e_j-(\frac{g(u,k)}{\rho}); \frac{\sigma_1}{\rho},\ldots,\frac{\sigma_r}{\rho})_{1,p},(b_j)_{1,Q}:(d_{1j})_{1,q_1};\ldots;(d_{rj})_{1,q_r}\end{matrix}\right.\right]$$

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